
BLUE AND BRIGHTER LEDs
IEEE
SPECTRUM
THE
MOON
LANDING
A 25th Anniversary
Perspective
JULY 1994
THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.

Newslog

MAY 3. China's **Ministry of Electronics Industry** said it had chosen **IBM Corp.** to lead the nation's Golden Bridge project, which will link some 500 cities to a national information highway data network. The project is one of three initiatives designed to modernize China's data communications and computing infrastructure.

MAY 3. Computer Sciences Corp., El Segundo, Calif., said it had received an eight-year contract worth US $1.05 billion to provide information support for NASA's **Marshall Space Flight Center**, Huntsville, Ala.

MAY 6. Digital Equipment Corp., Maynard, Mass., said it would cut at least 20 000 more of its 92 000 employees within the next two years.

MAY 9. AT&T Corp. said it had won a seven-year contract worth over $4 billion to modernize **Saudi Arabia's** telecommunications network. The project includes the installation of digital switching and optical-fiber equipment for 1.5 million phone lines.

MAY 12. South Korea's **Samsung Electronics** and **Goldstar Co.** announced that they would begin mass production of active-matrix liquid crystal displays next year.

MAY 12. A team at **IBM Corp.**'s Almaden Research Center, San Jose, Calif., said it had developed a way to store 90 percent more video, music, or computer data on optical discs. The technique would permit several movies, or 12 hours of music, or a million pages of text to fit in the 6.5 gigabits of a single compact disc. The process involves gluing CDs into layered stacks, from which information can be retrieved by focusing the laser beam on the appropriate layer.

MAY 12. Researchers at **Nippon Telegraph & Telephone Corp.**, Tokyo, said they had discovered how to control a semiconductor material's tendency to "grow" orderly rows of microcrystals called quantum dots. Basically, the group condensed a heavy-metal vapor onto a specially prepared gallium arsenide crystal, which then grew a regularly spaced field of the tiny box-like microcrystals, each roughly one seventh of a micrometer wide. Then, by varying the composition of the GaAs crystal, the team found it could reliably control the microcrystals' size and spacing. The finding could transform the way ICs are manufactured.

MAY 12. Shinsegi Mobile Telecom Co., Seoul, said it had selected four U.S. companies to share in a consortium to build South Korea's second cellular network. The four are **Pacific Telesis Group, Southwestern Bell, GTE,** and **Qualcomm.**

MAY 13. Bulgaria's **National Electricity Co.** said it would invest a further $200 million to upgrade and make safer four Soviet-designed 440-MW reactors at the Kozloduy nuclear power complex. Kozloduy provides 40 percent of the country's power and cannot be phased out until aternative power sources are secured.

MAY 16. Japan's **Hitachi Ltd.** and **National Space Development Agency** said they had developed a process for protecting standard semiconductor devices against radiation in space. In a test, the team covered a 32-bit microprocessor with a 1.2-μm film of silicon nitride, then exposed it to gamma rays. The prototype remained operational even after 10 hours, whereas an untreated microprocessor begins malfunctioning after 6 minutes.

MAY 17. The **New York State Public Service Commission** said it would allow **Rochester Telephone Corp.** to spin off a nonregulated unit to bundle and sell various telecommunications services—if the telco allowed outsiders to offer local telephone service. **Time Warner Inc.**'s cable unit said it would start providing phone service to its customers in the Rochester area, linking its cable lines with Rochester Telephone's local network.

MAY 19. Bell Atlantic Corp., Philadelphia, announced plans to build an $11 billion commercial multimedia information network that will serve more than 8.5 million homes in the Middle Atlantic region by the year 2000. The project aims to deliver interactive voice, data, and video services to one million homes by the end of 1995. **AT&T Corp.** will be the project's primary supplier and contractor, and **General Instruments Corp.**, Chicago, will supply set-top terminals and data-encryption gear.

MAY 19. Intel Corp., Santa Clara, Calif., and **General Instrument Corp.**, Chicago, said they had signed agreements with **Tele-Communications Inc.**, Denver, Colo., and **Rogers Cablesystems Ltd.** of Canada to develop a means of transmitting computer data over cable systems at up to 30 Mb/s—more than 1000 times the rate of most modems used with phone lines. The goal: to deliver multimedia to PCs in the home.

MAY 20. Southwestern Bell Corp., San Antonio, Texas, said it had asked Maryland's Public Service Commission for permission to provide local telephone service to cable customers in Montgomery County, Md., a **Bell Atlantic Corp.** region. The move would be the first assault by a Baby Bell on a sibling's local phone business.

MAY 24. GTE Corp., Stamford, Conn., which provides phone services in 33 states, said it would build a video network linking seven million homes in competing with the cable industry. GTE Telephone Operations, Irving, Texas, expects to deliver broadcast, cable, and interactive TV programming in 66 cities by 2003.

MAY 31. Researchers at the **Princeton Plasma Physics Laboratory** announced that their Tokamak Fusion Test Reactor had produced a burst of 9 MW of fusion power in a magnetically confined plasma consisting of deuterium and tritium, a world record. Not only was output power much higher than the 6.2 MW produced by the last experimental run in December, but other fusion conditions—such as greater effectiveness of the magnets—also showed improvement.

JUNE 2. Computer scientist **Matthew Blaze** at **AT&T Bell Laboratories** said he had uncovered a basic flaw in the **Clipper chip**, which the Clinton administration has been promoting as a way to allow law enforcement officials to eavesdrop on electronically scrambled phone and computer conversations. Blaze said a person with sufficient computer skills could use the Clipper technology to encode a message so that even the Government could not crack it.

JUNE 7. Raytheon Co., Lexington, Mass., said it had joined a consortium of U.S., Japanese, and French companies to build field-emission flat-panel displays for both military and commercial uses. Members include **Texas Instruments,** France's **Pixel International,** and **Futaba Corp.** of Japan.

Preview:
JULY 24–29. The **Federal Communications Commission** (FCC), Washington, D.C., will begin auctioning off the public airwaves for: 10 radio licenses for nationwide narrowband personal communications services (PCS); 600 licenses for interactive video and data services in metropolitan areas; and in December licenses for broadband wireless PCS services. For more information, call the FCC Auctions Hotline, 202-418-1400.

Sally Cahur

JULY 1994 VOLUME 31 NUMBER 7

IEEE SPECTRUM

SPECIAL REPORT

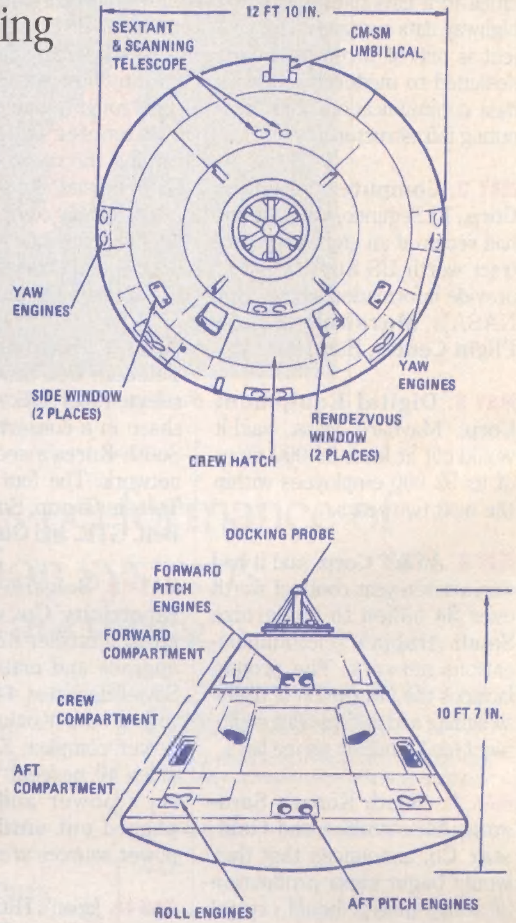
16 L+25: a quarter century after the Apollo landing

By DAVE DOOLING

When the Apollo 11 rose into space, it was guided to the moon by a mainly pre-IC, onboard computer with only 36 kilobytes of memory. Even the rendezvous of the lander with the Command/ Service Module [designs shown at far right] employed a technique practiced only once before in lunar orbit. Some in the 1960s had also feared the dust on the lunar surface might swallow up both lander and astronauts, but the first footprint on the moon [upper left] shows why it did not: without air between the particles, the subsurface dust compacts efficiently. Back then, the United States was racing against the USSR; in an early-'60s painting [lower left], those waving from the moon are Soviet cosmonauts, like the painter himself, Alexei Leonov, who in 1965 became the first man to walk in space.


National Aeronautics and Space Administration


Novosti Press Agency

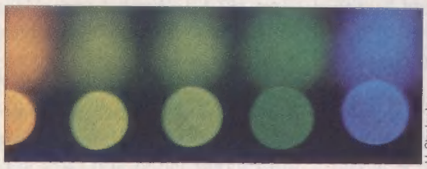


North American Aviation

ADVANCED TECHNOLOGY

30 Hooray for the LEDs bright and blue

By KENNETH I. WERNER


J. Stanley Inc.

The gradually evolving technology of light-emitting diodes has of late made a quantum leap. These semiconductor devices are usurping some of the slots that, till now, had been filled by incandescent lamps and cathode-ray tubes.

PROFESSION

40 A Capitol experience

By GEORGE F. SWETNAM JR.

What would it be like for an electrical engineer to put his expertise to work in the United States Congress? This one tried it—as an IEEE Congressional Science Fellow. His reflections on his year as a legislative assistant are full of fascinating insights into how the U.S. government works.

ADVANCED TECHNOLOGY

44 Multimedia's push into power plant control

By KLAUS ZINSER and FLORIAN FRISCHENSCHLAGER

Integrated with visualization and advanced document retrieval, this novel approach from Germany also enhances staff collaboration.

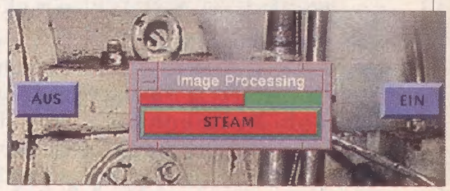


ABB Corporate Research

Gerry Gropp/Sipa

Cover: Twenty-five years ago this month—on July 20, 1969, at 10:56 p.m. EDT—men set foot on the moon for the first time. A look back on that historic start of an all-too-brief era of manned lunar exploration focuses on the impressive engineering tradeoffs underlying the feat. A look ahead stirs the apprehension that this or future generations may never again know the exhilaration of walking on alien worlds. Illustration by Mitchell Heinze. [p. 16]

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Forum

Fire power

I found the article "EEs in the boardroom" [April, pp. 20–26] well timed and encouraging. In a recent reorganization at my company, E-Systems, Greenville Texas Division, all the aircraft modification engineering first-level and second-level electrical managers were demoted or let go. Prior to the restructuring, seven first-level electrical managers and one second-level electrical section manager led teams of EEs in the design of electrical systems for both commercial and military aircraft. Eight first-level mechanical managers and one second-level mechanical manager were responsible for the design of both structural modifications and mechanical systems.

The new engineering architecture consists of six first-level managers and one second-level manager. Each of these first-level managers now leads a product group consisting of mechanical, electrical, and structural engineers. All the leadership positions were filled by members of the previous mechanical groups.

It appears that the company did not believe that any of the electrical managers had the skills and abilities to lead a product/combined team. My question remains, "Why not?"

Connie L. Gwin
Greenville, Texas

In "Layoffs should come last" [May, pp. 52–55], Helen Gracon and Maureen Clark paint a false picture of employment and layoffs. As the experience of Digital Equipment Corp. and IBM Corp. has demonstrated, it is harsher to employees and to stockholders to pursue a "no layoffs" policy than to maintain employment at levels justified by revenues.

Also, U.S. firms should reject rather than emulate European employment policies. National laws that pamper employees and make layoffs a last resort have rendered European firms increasingly noncompetitive. Those laws have also held back productivity growth for Europe's workers. As a result, Europe suffers from chronic high unemployment, as well as inflated manufacturing costs.

Management's goal must be keeping employees productive, not keeping employees. Changes in technologies and markets will continue to demand flexibility in employment policies. Thus, both employees and managers should see layoffs as a constructive, sometimes appropriate, response to the demands of the marketplace.

As a resource-management strategy, many firms (for example, Sun Microsystems) hold employee head count low by keeping contractor head count high. Less enlightened firms are increasing their flexibility by subcontracting tasks to workers they had previously laid off. For many ex-employees, being a contractor is more stimulating and rewarding than being employed; the only thing better than employment is self-employment.

In a market economy, the employee is responsible for being employable and employed. No employee should surrender that responsibility to an employer, for the best employment security is holding, and honing, marketable skills and knowledge.

David A. Nelson
Kirkland, Wash.

Am I the only one who thinks that somebody has multiple poles in the right-half plane? Please note the following two items in the March issue:

P. 1, Newslog: JAN 11. Westinghouse Electric Corp., Pittsburgh, said it would lay off 3400 employees and a further 2600 through attrition within the next two years...

P. 68E, Recruitment advertisement: Westinghouse Science & Technology Center, for power electronics engineers.

I understand that corporations are always on the search for "qualified" personnel, but cannot the infamous "circle-bar-W" find sufficient qualified personnel out of 6000 employees? Methinks there is something rotten in Pittsburgh!

Don R. Brown
North Augusta, S.C.

Of trees and tonnage

In "The multimedia drive" [April, pp. 77–78], Richard Comerford stated that the Government Services Administration (GSA) saves 187 trees per month by not printing 1.1 million pages a month. A single page of paper weighs 4.58 grams, so 2000 sheets weigh 20 pounds, by definition, for "20 lb paper." Then 1.1 million sheets weigh about 11 000 lb.

Is that 187 trees? Does a tree weigh 59 lb? Boy, trees are getting smaller than ever these days!

Robert A. Pease
Santa Clara, Calif.

The author responds: Here is a more detailed breakdown. The GSA's monthly telephone bill was 1.1 million pages long. The GSA required two copies, or 2.2 million pages, which were replaced by the WORM and erasable disk referred to in the article.

The actual weight of the paper was 11 tons (22 000 lb). According to paper industry figures, it takes 187 trees to create 11 tons of paper, which means that the portion of each tree turned into paper weighs about 118 lb.

To make that much paper, by the way, it also takes 27.5 barrels of oil and produces 27.5 cubic yards of waste. Also, it took about 750 cardboard boxes each month to deliver the set of invoices.

For more information, the contacts are AT&T Corp.'s Susan Reiche, 301-608-5113, and David Kalstrom, Plasmon Data Systems, 408-956-9400.

A solid education

It was with some interest that I read Madhu S. Gupta's column "In academe's grungy groves" on the shortcomings of education [March, p. 16]. Gupta's anecdotes caused me to reflect on my own undergraduate experiences, which might provide an interesting counterpoint.

I am a graduate of an engineering university unique in its concept: the United States Military Academy at West Point. West Point has taught engineering longer than any other school in the country—since 1802.

The teaching methodology used today is quite similar to that used in 1802. Senior Army officers, who are experts in their fields, form the core of the faculty. These senior officers are supported by outstanding young officers drawn from the field army. No research takes place at West Point, and professors are not subject to the "publish or perish" philosophy.

The result is a faculty devoted to its students. The primary mission of all professors, from the department head down to the most junior associate professor, is teaching. The advantages of this structure can be readily seen in its execution. When I was a senior, over half my classes were taught by full professors. Moreover, they presided at every single lecture and lab session.

All my professors were more than willing to spend time with any student who needed it. I can recall countless times when instructors stayed late to provide additional instruction. On many occasions, I saw professors in the labs late at night, on the weekends, and on holidays. These professors were not working on their own research—they were assisting students in the learning process.

The outcome was that I received an absolutely outstanding education in engineering. I was told to push my limits, and

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whenever I reached them, an instructor was there to extend them. When I wished to go off on a tangent to the instruction, I was allowed, even encouraged, to do so. Without a doubt, every single one of my classmates received a solid grounding in his field—because our instructors made sure we did.

Granted, West Point enjoys a distinct advantage because the core of our funding is provided by the government. Nonetheless, I owe much of my education to the faculty's relentless pursuit of other sources of support, especially industry grants. I suspect that other universities could benefit equally from the generosity of non-government institutions, were their faculty to invest the needed effort.

A strong argument against the West Point method is the fact that the university-government-industry research connection has been responsible for the current position of the United States as the world leader in technology. I would have to agree. It would not be a good thing if every U.S. school were to shun research. I do believe, however, that the current balance between scholarship and research is tilted badly to the research side—perhaps a case of too much of a good thing.

Glenn C. Hollister
Tokyo, Japan

Does Gupta not realize that universities are no longer academic institutes but legitimate business enterprises where research and teaching are secondary to income generation? After all, universities take only the very best students, who are not dependent on the lecturers' teaching skills. Why waste valuable management and administration time in teaching? Besides, what do students think they are—fee-paying customers?

I find it difficult to believe that a supervisor would allow a student to appear as the primary author in any publication. It is well known that the supervisor's name is always first (whether or not he has read the paper). Moreover, most transactions are only read by those dedicated enough to wade through the spelling errors, grammatical mistakes, and other such obstacles. This, by definition, considerably reduces the likelihood of such a paper being read by anyone in academic authority. Furthermore, if simultaneous publication gives the academic institute in question a better chance of obtaining grants, then that's no less ethical than multiple new issue share applications, tax evasion, and other "creative" business practices.

As for candidates possessing only a narrow focus and little background, what does Gupta want? Employees with well-rounded engineering skills and experience? If people with these abilities were available, they would almost certainly have chosen an alternative career to engineering academia. For this we should be thankful, as otherwise we would be in danger of these fellows telling our industrial sponsors how the job could be done in half the time at half the cost. Then where would our grants and promotion prospects be?!

G. J. Monkman
Regensburg, Germany

To your health

The readership might find a recent article from *Health* ["The Case of the Addled Electrician," May/June 1994, pp. 122–125] of value. It described the predicament of an electrician whose blood was found to contain high levels of lead and who, as a result, experienced stiffness in his joints, tingling in his hands, and mental deterioration.

After extensive testing and questioning, it was found that the man habitually chewed on the plastic coating of wire insulation. The chemical used to color the coating contained a great deal of lead. When he stopped chewing the plastic, his lead levels and general health returned to normal.

While many EEs are theoretical types, I imagine that enough get hands-on contact to make the lead issue a possible legitimate concern. Although gnawing on a 6-inch length of insulation may not seem particularly professional, in my experience it is common enough.

Anthony Faulise
Wethersfield, Conn.

I wish to respond to three letters in the April Forum critical of Paul Brodeur and his book *Currents of Death.* He is described as an "environmental gadfly" who presents only "anecdotal evidence without a single reference to the literature"—not much was available in 1989—or who "rarely used refereed references." However, the work of all U.S. scientists and institutions doing relevant work was referenced.

Currents of Death does not pretend to be a scientific treatise, which the public would never read. It is a popularized account intended to arouse public awareness of an environmental issue whose study was being impeded by powerful interests. Directly quoted testimony from public hearings gives a good picture of this opposition.

Appropriate changes in utility wiring will ultimately cost billions of dollars. Sweden has begun the changeover.

My original suggestion to superconductor power engineers—to consider the effects of 60-cps magnetic fields on human health—still stands.

John G. Sinclair Jr.
Little River, Calif.

The real issue is that there has generally been far more coverage in the popular press than in the technical journals about the real or perceived health effects of long-term exposure to low-frequency magnetic fields. While the evidence is far from conclusive, many of us are concerned about the number of epidemiological studies that have indicated increased health risks associated with long-term exposure to electromagnetic fields. I understand that although extensive research is continuing, no definite results are anticipated in the near future. Therefore, it is important that all of the developments be openly discussed, including research activities, the actions of utility companies and other industrial organizations, and any legislative actions being considered or implemented both in the United States and worldwide. This will enable us as professional electrical engineers to provide rational advice on this controversial topic.

Robert B. Fisher
Jamison, Pa.

Logic triumphant

As an adjunct to Jerome Peirick's letter [March, p. 6] replying to an earlier letter [January, pp. 8–9], I wish to point interested readers to an article in *The Atlantic Monthly* [February, pp. 35–37]. It confirms Peirick's argument: if B followed A, then it does not necessarily mean that A caused B (thus the Strategic Defense Initiative has not been proved to be a large factor in the collapse of the Soviet Union).

In fact, the article cites evidence that the initiative actually prolonged the existence of the Soviet Union, directly contradicting Heembrock's letter.

Many congratulations are due to Peirick for his resolute application of engineering logic, even in a distinctly nonengineering domain.

Seamus Dunphy
Donegal Town, Ireland

Corrections

On pp. 70, 80, and 82 of the April issue, the 800 number for PLI Inc., of Fremont, Calif., should have been 1-800-288-8754.

On p. 21 of the May issue, credit for Fig. 2 should have been given to the University of California, Berkeley Sensor and Actuator Center.—*Ed.*

Readers are invited to comment in this department on material previously published in *IEEE Spectrum;* on the policies and operations of the IEEE; and on technical, economic, or social matters of interest to the electrical and electronics engineering profession. Short, concise letters are preferred. The Editor reserves the right to limit debate on controversial issues. Contact: Forum, *IEEE Spectrum,* 345 E. 47th St., New York, NY 10017, U.S.A.; fax, 212-705-7453. The e-mail (Internet) address is n.hantman@ieee.org. For more information, call 212-705-7305 and ask for the Author's Guide.

Books

Hubris of a heavyweight

Jef Raskin

Steve Jobs & The NeXT Big Thing.
Stross, Randall E., Atheneum, New York, 1993, 374 pp., $24.

Having worked closely with NeXT founder Steve Jobs, I had every reason to expect the NeXT computer to be a disaster. But until I read this book, I had no idea just how much of a disaster it really was.

The story told is one of a colossal waste of time, talent, and money. Steve Jobs is depicted as a charismatic but massively incompetent leader, lacking in management and technical skills, to say nothing of elementary social graces. The stupidities committed at NeXT Computer Inc. are legion, and some atrocious decisions are recounted in satisfying depth.

The recent past has seen a spate of books and articles on the history of high technology. When they touch on events of which I have firsthand knowledge, they are often wildly inaccurate, full of oversimplifications and the occasional anachronism. Their authors generally skimp on research—well over half of the Silicon Valley "histories" and memoirs on my shelf have no notes or citations at all. Therefore, my biggest concern about this book was how credible it would be, and on this score it compares reasonably well with others of the genre.

Individuals whom I know personally are recognizably portrayed; events in which I participated are usually recounted much as they happened. That said, there are errors and lacunae for which there is little excuse. But let's look at the story first.

Steve Jobs had two skills honed to unusual keenness. Stross relates that "it was uncanny how deftly Jobs knew what each person most would want to hear, hitting the right buttons, with visions of greatness combined with measured dollops of flattery ('Hey, I hear you're the hottest designer on the planet')." Jobs extracted millions of dollars from the Japanese company Canon Inc. and from Ross Perot—who appears more a fool than a potential U.S. president ("that sucking sound" turns out to have been Jobs working on Perot's wallet).

Jobs's other skill was an instinct to negotiate right to the brink and on occasion, like the coyote in the Road Runner cartoons, to cross just over the edge without falling. Unlike the coyote, however, Jobs ignored the abyss below, and as a result seemed blissfully unaware of how precipitous his fall could be. And fall he did, pulling down with him $250 million in direct expenses at NeXT, plus the trust and/or money of employees, dealers, vendors, and customers.

In the early days of Apple and NeXT, his negotiating ability obtained for those companies a clear financial advantage over less daring competitors. His ability to read people's ambitions helped him snare stars who seemed beyond the reach of what were then start-up companies.

On the other hand, some people took advantage of Jobs's delusions. One engineer I knew chose to work at NeXT after working with Jobs at Apple because, as he told me, "At NeXT, I'll get to play with whatever toys I want to—Jobs won't know the difference." And he was right.

The waste of money and distortion of priorities at NeXT boggle the mind. Stross tells it well and compellingly; a case in point is the story of how the computer's provocative shape came into being. "Jobs was captivated by the idea of using a cube-shaped box to house the computer's electronic innards, and like other ideas he embraced, no amount of contrary reasoning could force him to loosen his grip," Stross writes. Jobs decreed that the cube would be 1 foot on a side (strange that he did not choose a more "with it" metric dimension). Then he insisted upon giving an outside designer a free hand, paying him an exorbitant fee.

Jobs and the designer seemed "oblivious to the possibility that NeXT's prospective customers would be more interested in what the computer could *do* than in how its sleek shape gave it claim to a place in the Smithsonian," and they decreed that the cube was to be as true a cube as mankind could make, with no draft to allow it to release from the mold.

Jobs also insisted the case be made of magnesium. Metal has its advantages, such as rigidity and electromagnetic shielding. But magnesium was a strange choice: it is dangerously flammable, far more expensive than plastic, and hard to mold to cosmetic quality. The complex mold the design required cost $650 000, but left parting lines, which at first were removed by hand and later by a $150 000 robotic sanding machine. Magnesium is difficult to paint, and Jobs compounded the problem by insisting that a certain black be used—which would not adhere.

Still, he was unyielding. "When underlings protested that specifications for the Cube contradicted the laws of physics, Jobs would wave the objections away," Stross found.

As expensive as the (eventually abandoned) box was, the amount was nothing compared to the sums thrown at the factory. "Machines were purchased, installed, and pulled out on Jobs's whim," Stross recounts. "All the assembly-line machines and robots at NeXT's plant had to be repainted to match, just as Jobs had insisted at the Macintosh factory. He even demanded that the machines and robots be reengineered, no matter what the cost, so that the circuit-board assembly line moved boards from the right to the left, instead of the industry-standard from left to right."

Why? So that a certain balcony would give throngs of visiting customers a clearer view of the action. The customers, it turned out, never came.

Jobs's monomaniacal concern for appearances turned everything he touched into the antithesis of good design. Form did not follow function but was allowed to float unfettered. Those who saw the emperor had no intellectual clothes, so to speak, generally kept their mouths shut; the few who spoke out lost their sinecure. Jobs was Zeus in his own pantheon, and those that did not acknowledge his godhead had no place on Mount Olympus.

As good as Jobs was at landing people, he had little idea of how to keep them. His peculiar lack of management skills was barely held in check at Apple. At NeXT, where he was in sole charge, his capriciousness knew no bounds. Stross tells of one hiree who, on his first day at work, did little but listen silently, like the other new employees, to Jobs's orientation talk. Immediately thereafter, Jobs ordered him fired because he had decided that this person was not "smart."

Although such tales appall and astound, the overall effectiveness of the book is undermined by minor but annoying inaccuracies. I am always surprised when a historian of contemporary events fails to talk to people involved in them. Though Stross describes himself as a historian, his book suffers from an ahistorical view of the industry and a journalist's hasty accumulation of unnecessary detail and errors. For example, the book that initially specified the Macintosh was called *The Book of Macintosh*, but Stross says it was the *Macintosh Documents*. There are many such unnecessary slips.

There are big mistakes, too. "... Like Old Testament genealogy, every important development in personal computers traces back to this same single source"—Xerox Corp.'s Palo Alto Research Center (PARC),

Books

(Continued from p. 8)

founded in 1970. To be sure, PARC's influence was broad, deep, and beneficial, but it was by no means the "single source" of "every important development." Stross's blanket claim ignores the influence of Ivan Sutherland's far earlier Sketchpad system; Douglas C. Engelbart's prior conception of the mouse and windows; the fact that the all-important invention of the microprocessor itself did not take place at PARC; and that the people who created the early personal computers (Apple I, SOL, Poly 88, Imsai, Altair, PET, and so on) generally knew nothing of, and took nothing from, PARC.

Historians whenever possible use primary sources, such as the published works, notes, memos, and letters of the participants in events; but Stross's citations are almost all secondary, and thus he often perpetuates their errors. For example, he follows other sources in crediting PARC with giving Apple the idea of abandoning character generators and going to an all-graphic display architecture. Had he consulted primary sources, Stross might have uncovered the fact that this concept, as well as the computer's human factors and "what-you-see-is-what-you-get" rationale, had been promulgated by one of Apple's earliest employees years *before* PARC was founded.

Readers of this magazine may share my disappointment that there is no serious coverage of the solid computer science and engineering done at either Apple or NeXT. Like the many other authors of books on the history of the personal computer, Stross is apparently so attracted to the glitter and blinded by the money, intrigued by the business dealings, and fascinated by the excesses of the personalities that technical achievements are barely mentioned.

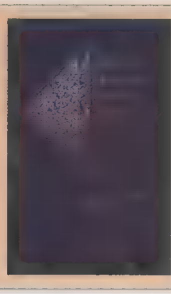
Is it because such episodes have little value when it comes time to sell the movie rights? The book follows the jinks and jibes of Jobs's untutored and undisciplined mind, but does not articulate the design decisions that went into the noteworthy NextStep object-oriented operating system and NeXT's pioneering work incorporating digital signal processing into a computer system. That part of the story, perhaps the most valuable of all, remains untold.

Jef Raskin (raskinjef@aol.com) was a computer center director and professor at the University of California, San Diego, but is best known for having created the Macintosh project at Apple. He named the new computer for his favorite kind of apple. A consultant, critic, and designer of human-machine interfaces, he writes and lectures extensively, working from his home in Pacifica, Calif. Also a composer of chamber music and scores for documentaries, his most recent publication is a three-volume set of recorder quartets.

Using light to fight crime

Terry Palmer

Optical Document Security.
Van Renesse, Rudolf L. (ed.), Artech House Inc., Norwood, Mass., 1994, 370 pp., $89.



Like the shimmering and colorful object on its cover, this book's title intrigues and puzzles. "What does the author define as a 'document'?" "Aren't holograms used to deter counterfeiting?" "Why doesn't the U.S. use holograms to protect its currency from counterfeiters?" "What other types of optical techniques may defeat counterfeiters?"

Answers to these and other questions are to be found in this book, the first devoted to the use of optical techniques to counter forgery and counterfeiting. Readers hoping for exciting stories about dastardly forgeries and the brilliant techniques used to foil them will, however, be disappointed. This is a solid, sober, technical book on optics and forensic science written by internationally renowned experts in document security.

While intended for nontechnical as well as technical people engaged in document security, the book cannot be fully appreciated without a one-semester college course in optics, backed by a two-semester, calculus-based introductory course in physics. All the same, nontechnical people working in the field could probably glean a basic understanding of most of these techniques by reading the overview chapters and scanning the remainder of the book. Both existing and proposed optical techniques to combat forgery and counterfeiting are covered.

In ancient times, officials secured a document against criminals by sealing it with wax and stamping it with a crest. The Romans minted coins with legal markings to deter counterfeiters. As technology advanced, civilizations developed new methods of securing their documents, banknotes, and paper currency, and of verifying the identity of individuals. New types of documents were born. Today, birth certificates, death certificates, driver's licenses, credit cards, and checks have all become cultural and social necessities.

In the meantime, photographic and copying equipment, scanners, computers, and laser and other kinds of printers have become inexpensive and ubiquitous. Predictably, criminals have exploited them. Photography, for instance, enabled criminals to make illegal copies of identification and other documents. Like the printing press before them, copiers have enabled criminals to replicate such documents, and paper

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he 1992 Winter Olympics that tickets to events could weighing several proposals, the idea of weaving iri- into the fabric of the ticket. kets were made on various ne of which could replicate e iridescent thread.

partments of transportation ates are all concerned about ver's licenses. The State of ats forgeries with various ues, including a hologram. is sophisticated enough to n by forgers.

patented technique from andis & Gyr, exhibit motion and intensity as a function of Many countries employ them securing their banknotes, her documents. Van Renesse us "OK Kinegram" in this otect Austrian and Finnish Arabian, U.S., Singaporean, assports; German, Benelux, Schenegen visa stickers; and Italian police and Dutch ID cards.

and perhaps even washing or dunking.

Fourth, the technique should function under a variety of lighting conditions. Fifth, the technique should have no adverse effects on people or the environment. Finally, it should be recognizable by a machine.

Examples include iridescent threads, holograms, kinegrams, pixelgrams, and multilayer coatings. They have been applied to such diverse documents as tickets to the Olympic Games, driver's licenses, banknotes, and passports.

About that shimmering, unidentified object on the book's cover: though the book never identifies it, I believe it must be a pixelgram, a series of equally spaced pixels with varying grating periods that are etched

graphic display architecture. Had he consulted primary sources, Stross might have uncovered the fact that this concept, as well as the computer's human factors and "what-you-see-is-what-you-get" rationale, had been promulgated by one of Apple's earliest employees years *before* PARC was founded.

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In the meantime, photographic and copying equipment, scanners, computers, and laser and other kinds of printers have become inexpensive and ubiquitous. Predictably, criminals have exploited them. Photography, for instance, enabled criminals to make illegal copies of identification and other documents. Like the printing press before them, copiers have enabled criminals to replicate such documents, and paper

currency, with less time and cost. The same technology that permits desktop publishing also, regrettably, allows for desktop forgery.

As the text explains, document fraud is combatted by inspection at three levels. The first occurs with the actual transaction, as in the exchange of money between friends. This inspection is performed rapidly and by nonexperts. The other two levels are performed by trained individuals and more sophisticated methods. Clearly, most forgeries must be detected at the first level and most of the techniques described in this book are associated with that level.

First-level inspections, the book explains, should have six attributes. First, optical security should permit easy recognition of the legitimate document. Second, ■ manufacturer must be able to generate the document (with the particular optical security technique) in large quantities and inexpensively. Third, the security technique must suit the document's environment; on a dollar bill, for example, it must be completely functional throughout the bill's useful lifetime, surviving the normal wear and tear, and perhaps even washing or dunking.

Fourth, the technique should function under ■ variety of lighting conditions. Fifth, the technique should have no adverse effects on people or the environment. Finally, it should be recognizable by a machine.

Obviously, different security techniques are appropriate for different types of documents, and some documents rely on a combination of techniques. The first use of novel optical security techniques in detecting forgeries (as described in this book) was demonstrated in 1970 by ■ team of researchers at the 3M Co., Minneapolis, Minn. These researchers used the physics of retroreflectors much as highway safety engineers use them. Highway road signs often have thin retroreflector films, which when lit by headlights, beam their information back into the eyes of drivers.

In similar fashion, the 3M researchers painted a thin, clear retroreflector film over ■ standard laminated identification badge. The thin film did not obscure the badge information, and the badge turned black or displayed a company logo when illuminated.

Since then, forensic scientists have pursued other optical security techniques that editor Rudolf L. van Renesse classifies as either variant or invariant optically. Optically variant techniques usually refer to those that rely on changes in color or appearance as the viewing angle changes. Examples include iridescent threads, holograms, kinegrams, pixelgrams, and multilayer coatings. They have been applied to such diverse documents as tickets to the Olympic Games, driver's licenses, banknotes, and passports.

Officials at the 1992 Winter Olympics were concerned that tickets to events could be forged. After weighing several proposals, they settled on the idea of weaving iridescent threads into the fabric of the ticket. Copies of the tickets were made on various color copiers, none of which could replicate the effects of the iridescent thread.

The state departments of transportation in the United States are all concerned about forgeries of driver's licenses. The State of California combats forgeries with various optical techniques, including ■ hologram. The technique is sophisticated enough to elude duplication by forgers.

Kinegrams, a patented technique from Switzerland's Landis & Gyr, exhibit motion and change color and intensity ■ a function of viewing angle. Many countries employ them as a method of securing their banknotes, passports, and other documents. Van Renesse shows the famous "OK Kinegram" in this book; others protect Austrian and Finnish banknotes; Saudi Arabian, U.S., Singaporean, and Bruneian passports; German, Benelux, Singaporean, and Schenegen visa stickers; and Italian police and Dutch ID cards.

About that shimmering, unidentified object on the book's cover: though the book never identifies it, I believe it must be ■ pixelgram, ■ series of equally spaced pixels with varying grating periods that are etched

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Books

(Continued from p. 11)

into a metalized surface. It has not been employed in any commercial projects to date, though it appeared on Australia's 1988 commemorative $10 banknote.

Optically invariant techniques do not change colors or depend on any tilting of the document to verify security. Some are old and well known, including watermarks, intaglio printing (thick ink pressed deep into paper at high pressures), and the use of special papers. The U.S. Department of the Treasury prints currency with intaglio technology on special paper. In addition, Treasury officials have mixed magnetic pigments with the ink for precise currency identification.

Such techniques have evolved to counter increasingly sophisticated methods of forgery and counterfeiting. Recent enhancements of intaglio technology enable printers to incorporate extremely fine lines in their documents. These fine lines are difficult for counterfeiters to replicate and are beyond the resolution of current scanners.

Examples of lesser known invariant optical techniques include the application of phosphors and fluorescent chemicals, and the etching of patterns by laser engraving. Van Renesse alludes to the fact that some currencies use phosphorescent and fluorescent fibers activated by ultraviolet light.

I suggest the following enhancements to any future editions of this book. First, the authors should address a wider audience by giving more examples of practical applications. Only document-security buffs, surely a tiny group, enjoy reading about clever security techniques with no known application. Second, for greater uniformity and less redundancy, the editor should get all the authors to follow the same format. Third, the book should close with a summary of the work and discuss future directions for this interesting and important field.

Terry L. Palmer (M) is a Huntsville, Ala.-based writer and consultant on optics, computers, and education. He is a former president of the Huntsville chapter of the Lasers and Electro Optics Society and is a member of several IEEE Societies. He has 17 years of experience in aerospace engineering and science.

EDITOR: Glenn Zorpette

Recent Books

Aeris for Windows and DOS: Automated Editing and Rapid Info-processing System, Version 2.0. *Gregory, D. J.*, and *BlueRithm Software*, BlueRithm Software, Colbert, Wash., 1993, 90 pp. (each), $129.95 (each).

Adventures in Flight Simulator, Version 5: The Ultimate Desktop Pilot's Guide. *Trimble, Timothy*, Microsoft Press, Redmond, Wash., 1994, 256 pp., $22.95.

PC Programmer's Handbook, 2nd edition. *Sanchez, Julio*, and *Canton, Maria P.*, McGraw-Hill, New York, 1994, 524 pp., $39.95.

Adaptive Fuzzy Systems and Control: Design and Stability Analysis. *Wang, Li-Xin*, Prentice Hall, Englewood Cliffs, N.J., 1994, 232 pp., $55.

UNIX Developer's Took Kit. *Leininger, Kevin E.*, McGraw-Hill, New York, 1994, 569 pp., $65 (hardcover), $49.95 (paperback).

A Prelude to Neural Networks: Adaptive and Learning Systems. Ed. *Mendel, Jerry M.*, Prentice Hall, Englewood Cliffs, N.J., 1994, 444 pp., $29.

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Multichip Modules and Related Technologies: MCM, TAB, and COB Design. *Ginsberg, Gerald L.*, and *Schnorr, Donald P.*, McGraw-Hill, New York, 1994, 290 pp., $55.

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Computational Geometry in C. *O'Rourke, Joseph*, Cambridge University Press, New York, 1994, 346 pp., $59.95 (hardcover), $24.95 (paperback).

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OSF DCE: Guide to Developing Distributed Applications. *Lockhart, Harold W., Jr.*, McGraw-Hill, New York, 1994, 561 pp., $59.95.

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ATM User-Network Interface Specification, Version 3.0. *The ATM Forum*, Prentice Hall, Englewood Cliffs, N.J., 1993, 389 pp., $34.

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Hands-On Internet: A Beginning Guide for PC Users. *Sachs, David*, and *Stair, Henry*, Prentice Hall, Englewood Cliffs, N.J., 1994, 275 pp., $29.95.

Solid State Physics, Vol. 48. Eds. *Ehrenreich, Henry*, and *Spaepen, Frans*, Academic Press, New York, 1994, 434 pp., $49.

Internet: Mailing Lists. Eds. *Hardie, Edward T.L.*, and *Neou, Vivian*, Prentice Hall, Englewood Cliffs, N.J., 1994, 582 pp., $29.

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Spatial Vision in Humans and Robots. Eds. *Harris, Laurence*, and *Jenkin, Michael*, Cambridge University Press, New York, 1993, 448 pp., $59.95.

Digital Signal Processing: A Laboratory Approach Using PC-DSP. *Alkin, Oktay*, Prentice Hall, Englewood Cliffs, N.J., 1994, 213 pp., $33.

Semiconductor Devices: An Introduction. *Singh, Jasprit*, McGraw-Hill, New York, 1994, 669 pp., $53.97.

Engineering Real Time Systems. *Braek, Rolv*, and *Haugen, Oystein*, Prentice Hall, Englewood Cliffs, N.J., 1993, 398 pp., $45.

Synthetic Diamond: Emerging CVD Science and Technology. Eds. *Spear, Karl*, and *Dismukes, John P.*, John Wiley & Sons, New York, 1994, 663 pp., $85.

Q Factor. *Kajfez, Darko*, Vector Fields, University of Mississippi, Miss., 1994, 174 pp., $69 (diskette included).

Electromagnetic Waves. *Staelin, David H., et al.*, Prentice Hall, Englewood Cliffs, N.J., 1994, 562 pp., $62.

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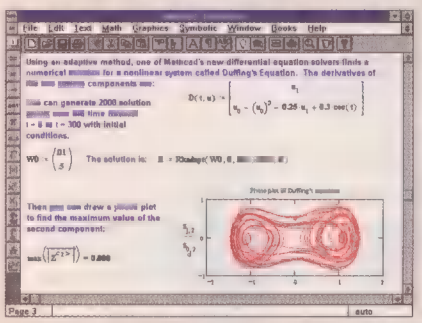

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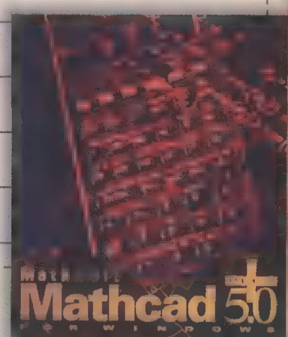

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Calendar

JULY

International Electron Devices and Materials Symposium (ED); July 13–15; National Chiao Tung University, Taiwan; Chien-Ping Lee, EE Department, National Chiao Tung University, Hsin Chu 30050, Taiwan; (886+35) 726 100, ext. 7718; fax, 713 403.

Hong Kong Electron Devices Meeting (ED); July 18; University of Science and Technology, Kowloon, Hong Kong; Man Wong, Department of Electrical and Electronics Engineering, University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong; (852) 358 7057; fax, (852) 358 148

International Conference on Emerging Optoelectronics Technologies (ED, LEO); July 18–22; Indian Institute of Science, Bangalore, India; Krishna Shenai, 4617 Engineering Hall, Department of Electrical and Computer Engineering, 1415 Johnson Dr., University of Wisconsin–Madison, Madison, WI 53706-1691; 608-265-3806; fax, 608-262-1267.

31st Nuclear and Space Radiation Effects Conference—NSREC (NPS); July 18–22; Westin La Paloma Resort, Tucson, Ariz.; NSREC Vice Chairman Publicity, UTMC, 1575 Garden of the Gods Rd., Colorado Springs, CO 80907; 719-594-8035; fax, 719-594-8187.

Symposium on Autonomous Underwater Vehicle Technology—AUV '94 (OE); July 19–20; Cambridge Center Marriott, Massachusetts; Claude Brancart, Charles Stark Draper Laboratories, 555 Technology Square, Cambridge, MA 02139; 617-258-3106.

Sixth International Conference on Electronic Engineering in Oceanography (UKRI Section); July 19–21; Churchill College, Cambridge University, England; Louise Bousfield, Conference Organizer, Institution of Electrical Engineers Conference Services, Savoy Place, London WC2R OBL, England; (44+71) 344 5467; fax, (44+71) 497 3633.

Power Engineering Society Summer Meeting (PE); July 24–28; Hilton Hotel, San Francisco, California; B.M. Speckman, Pacific Gas & Electric Co., 77 Beale St., Room 2397, San Francisco, CA 94105; 415-973-2875.

International Conference on Science and Technology of Synthetic Metals (ED); July 24–29; Hotel Intercontinental, Seoul, Korea; Yung Woo Park, Physics Department, Seoul National University, Seoul 151-742, Korea; (82+2) 880 6607; fax, (82+2) 873 7037.

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An Introduction to Ultrasonic Motors. *Sashida, Toshiiku*, and *Kenjo, Takashi*, Oxford University Press, New York, 1993, 242 pp., $82.50.

Electromagnetic Waves. *Staelin, David H., et al.*, Prentice Hall, Englewood Cliffs, N.J., 1994, 562 pp., $62.

Elements of Engineering Electromagnetics, 4th edition. *Rao, Nannapaneni Narayana*, Prentice Hall, Englewood Cliffs, N.J., 1994, 721 pp., $68.

Biomedical Signal Processing. *Akay, Metin*, Academic Press, New York, 1994, 377 pp., $79.

Digital Design Principles & Practices, 2nd edition. *Wakerly, John F.*, Prentice Hall, Englewood Cliffs, N.J., 1994, 840 pp., $67.

Arsenic in the Environment, Part II: Human Health and Ecosystem Effects. Ed. *Nriagu, Jerome O.*, John Wiley & Sons, New York, 1994, 293 pp., $85.

The Analysis and Design of Linear Circuits. *Thomas, Roland E.*, and *Rosa, Albert J.*, Prentice Hall, Englewood Cliffs, N.J., 1994, 999 pp., $65.

McGraw-Hill Circuit Encyclopedia & Troubleshooting Guide, Vol. 2. *Lenk, J. D.*, McGraw-Hill, New York, 1994, 691 pp., $59.50.

Information Modeling: The EXPRESS way. *Schenck, Douglas A.*, and *Wilson, Peter R.*, Oxford University Press, New York, 1994, 388 pp., $60.

Client/Server Computing: Architecture, Applications, and Distributed Systems Management. *Elbert, Bruce*, and *Martyna, Bobby*, Artech House, Norwood, Mass., 1994, 352 pp., $69.

Transmission Lines in Computer Engineering. *Rosenstark, Sol*, McGraw-Hill, New York, 1994, 211 pp., $50.

Optical Interconnection: Foundations and Applications. Eds. *Tocci, Christopher*, and *Caulfield, H. John*, Artech House, Norwood, Mass., 1994, 383 pp., $79.

1994 IC Master Directory of IC Manufacturer's Data Pages. *Howell, David M., et al.*, Hearst Business Publishing/UTP Division, New York, 1994, 796 pp., $84.50.

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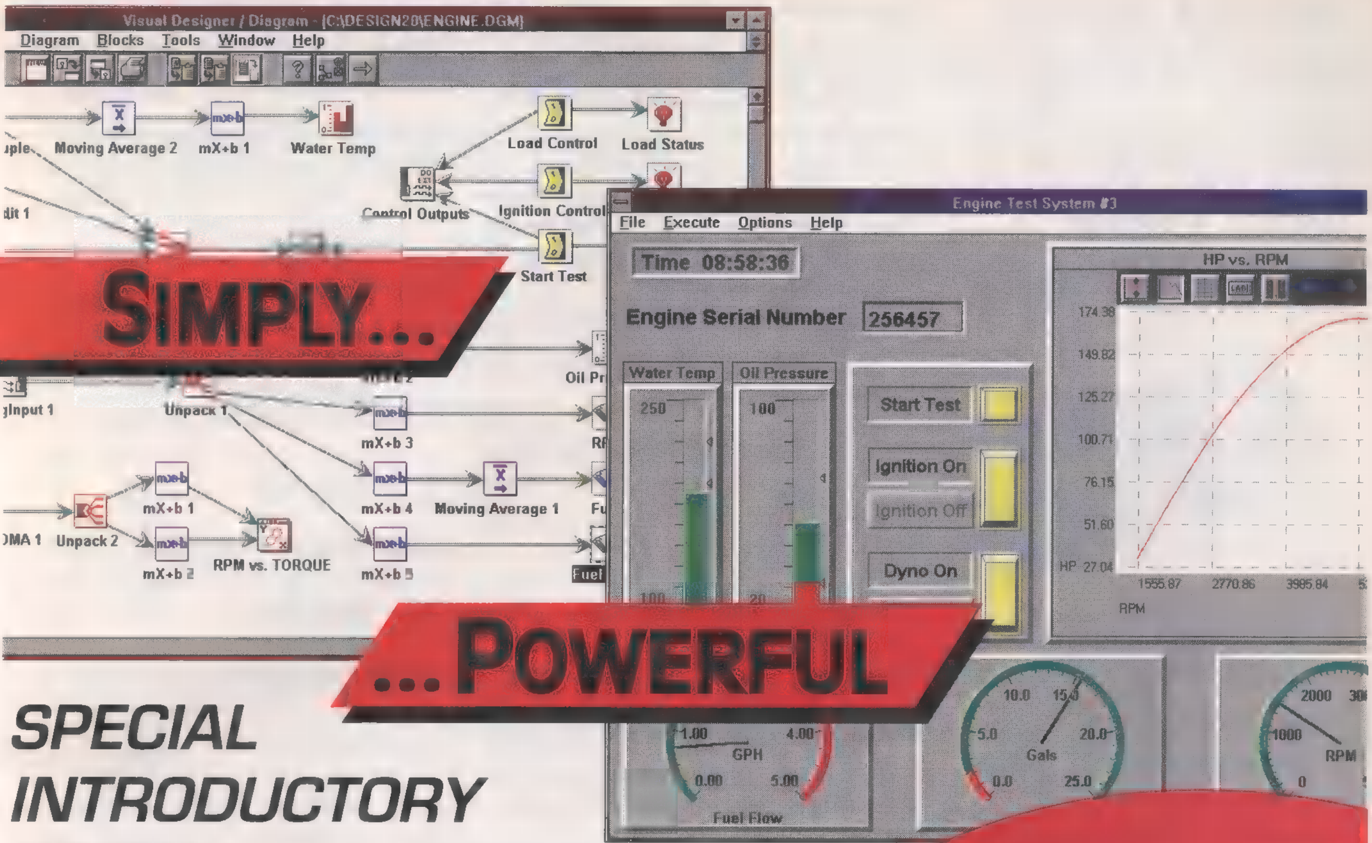
Theory of Algebraic Invariants. *Hilbert, David*, Cambridge University Press, New York, 1993, 191 pp., $39.95.

Dazzle 'em with Style: The Art of Oral Scientific Presentation. *Anholt, Robert R.H.*, W.H. Freeman and Company, New York, 1994, 200 pp., $11.95.

Applied System Identification. *Juang, Jer-*



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Recent books

Nan, Prentice Hall, Englewood Cliffs, N.J., 1994, 394 pp., $65.

1994 IC Master, Vol. 1: Selection Guides and Function Index; Vol. 2: Part Number Index/Guide Alternate Sources; Vol. 3: Advertisers Technical Data. *Howell, David M., et al.*, Hearst Publishing/UTP Division, New York, 1994, 3000 pp., $180 plus $10 shipping and handling.

The Next Great Thing: The Sun, the Stirling Engine, and the Drive to Change the World. *Shelton, Mark*, W.W. Norton & Company, New York, 1994, 272 pp., $25.

Handbook of Networking & Connectivity. Ed. *McClain, Gary R.*, Academic Press, New York, 1994, 415 pp., $39.95.

Digital Design Using ABEL. *Pellerin, David*, and *Holley, Michael*, Prentice Hall, Englewood Cliffs, N.J., 1994, 322 pp., $52.

Object-Oriented Graphics Programming in C++. *Stevens, Roger T.*, Academic Press, New York, 1994, 498 pp., $39.95.

Communication Systems Engineering. *Proakis, John G.*, and *Salehi, Masoud*, Prentice Hall, Englewood Cliffs, N.J., 1994, 889 pp., $68.

Cellular Radio Analog and Digital Systems. *Mehrotra, Asha*, Artech House, Norwood, Mass., 1994, 460 pp., $89.

Perturbation Signals for System Identification. *Godfrey, Keith*, Prentice Hall, Englewood Cliffs, N.J., 1993, 439 pp., $58.

Virtual Reality ExCursions with Programs in C. *Watkins, Christopher*, and *Marenka, Stephen R.*, Academic Press, New York, 1994, 503 pp., $39.95.

Galileo: A Life. *Reston, James, Jr.*, HarperCollins, New York, 1994, 336 pp., $25.

An Introduction to U.S. Telecommunications Law. *Kennedy, Charles H.*, Artech House, Norwood, Mass., 1994, 169 pp., $59.

Project Management: Engineering, Technology, and Implementation. *Shtub, Avraham, et al.*, Prentice Hall, Englewood Cliffs, N.J., 1994, 634 pp., $66.67.

SPICE Applications Handbook, 2nd edition. *Hymowitz, Charles E.*, and *Meares, Lawrence G.*, Intusoft, San Pedro, Calif., 1994, 375 pp., $49.95.

Mobile Antenna Systems Handbook. Eds. *Fujimoto, K.*, and *James, J. R.*, Artech House, Norwood, Mass., 1994, 617 pp., $98.

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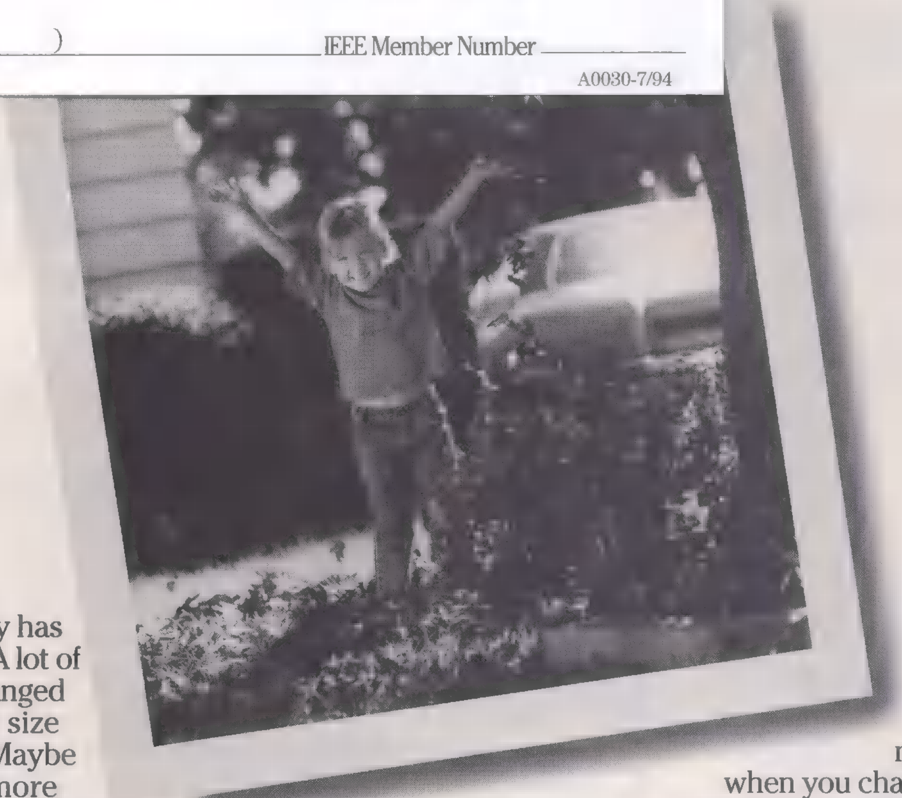

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Washington watch

Info future needs more planning, say engineers

More Government support for the information infrastructure is urged in a report by the National Research Council (NRC). The 285-page "Realizing the Information Future" was developed by leading computer scientists and engineers, who warn that without added effort by the Government, digital babble could ensue.

So far, the Clinton administration's involvement with the National Information Infrastructure (NII) has been mainly to create a vision of universal access to education, medical care, commerce, and so on. That is admirable but not enough, said the NRC panel chair, Leonard Kleinrock, a computer scientist at the University of California, Los Angeles. Unless steps are taken soon, the NII could be composed of duplicated infrastructures and services that do not work together.

Bearing the imprimatur of the National Academy of Sciences and its sister Academy of Engineering, the report says that Government should endorse the idea of an "open data network" and proposes a conceptual architecture.

"Market forces alone will not necessarily get us to the right place," said David Clark, who is a research scientist at the Massachusetts Institute of Technology in Cambridge. "Simple urging won't work."

The open data network would build on the Internet's strengths, but if it is to succeed needs new approaches to networking and standards. Clark, who was instrumental in the Internet's design and has helped plan the open data net, called the latter "a fairly significant intellectual contribution."

Basically, the model proposed is a four-layered architecture: the underlying bearer service; the transport services and representation standards; middleware services (like security, name servers, and electronic money); and the applications seen by users (teleconferencing, browsing, and so on).

The bearer service would decouple service characteristics from technology, so that the incorporation of new technology would not interfere with applications. The interface would be open, so that many vendors of services and applications may compete.

Though the panel did not address regulatory or legal issues, it urged Government action in other areas, including an expanded role for the Department of Education in developing networks for the precollege level.

Copies of the report are available from the National Academy Press (800-624-6242 or 202-334-3313). In addition, the report is to be available electronically through the Internet's World Wide Web.

DSS code blessed for unclassified data

A controversial algorithm for protecting unclassified Government data has been approved as the Digital Signature Standard (DSS) for all Federal departments, agencies, and their contractors. The terse announcement to reporters in May by the National Institute of Standards and Technology (NIST) mentioned nothing about the challenges of patent infringement or the murky involvement of the National Security Agency. So *Spectrum* had to ask.

"The standard was issued without a full

Washington watch

and complete resolution of the intellectual property issues," replied Lynn McNulty, an associate director at NIST, Gaithersburg, Md. Nevertheless, the Government, he said, believes the standard will hold up in court and plans to intervene in any lawsuits on behalf of a Government contractor.

The DSS, like techniques such as the commercial code-making method known as RSA, can verify the authenticity of an electronic file or message and also the identity of the sender. But compared with some other methods, the DSS has an edge in that the Government will not charge royalties to users. In addition, being decoupled from encryption, the DSS theoretically poses no export problems.

In recent weeks, DSS developments have been overshadowed by the Government's encryption proposal for the Clipper chip. The DSS, also known as Federal Information Processing Standard 186, becomes effective on Dec. 1. For more information, consult the *Federal Register* of May 19. For nongovernment work, it may be wise to consult a lawyer before making use of the standard—or at least to wait until the patent issue has been resolved.

'Paradise' for inventors

"The fruits of the human brain are an inexhaustible resource" that the Clinton administration is trying to protect, said the head of the U.S. Patent and Trademark Office, Bruce A. Lehman, during an IEEE-USA Intellectual Property symposium held in May.

Lehman is changing the incentives for his 1800 U.S. patent examiners to make the Patent and Trademark Office "an inventor's, not a lawyer's paradise." Accordingly, not only the quantity but also the quality of patents will be evaluated.

Anne K. Bingaman, the Justice Department's antitrust chief, said she is expanding her staff on intellectual property issues. "The protection of intellectual property ...makes people go out and design a better mousetrap," she said.

As to prevention of piracy, there are "still numerous problems" overseas, according to Joseph Papovich, the U.S. Trade Representative's deputy assistant for intellectual property. But the means for addressing problems have been boosted, resulting in "tremendous improvement." Papovich named China as the site of most of today's piracy. India and Argentina are also countries of concern, the latter only with re0gard to pharmaceuticals, he said.

For more information on the event, contact IEEE-USA at 202-785-0017

NSF aids city precollege science study

Nearly 2.5 million students could benefit from awards presented in May to nine cities by the National Science Foundation (NSF). The $135 million worth of awards is aimed at helping precollege students at urban schools get a better grasp of science, math, and technology

Minorities supply most of the students in many cities—83 percent in Baltimore are African-American, while 79 percent in El Paso are Hispanic. Those two cities received awards, as did Chicago, Cincinnati, Dallas, Detroit, Miami, New York City, and Phoenix. All told, 25 cities were judged eligible for the Urban Systemic Initiative program, eligibility being determined by the number of a city's school-age children living in poverty.

Luther Williams, the NSF's education and human resources' chief, said that a key goal of the program is to "confront one of the most intractable education issues of our time—the disturbing and continuing performance gap" between largely minority urban and largely white suburban students.

Begun last year, the program is seeking broad-based reforms, initiated by the cities, in curriculum and pedagogy, policy and budget. In May, for instance, New York City announced new math and science graduation requirements for its 1.1 million students and is creating 250 cluster schools to emphasize math, science, and technology.

Check the NSF's Science and Technology Information Service for details. E-mail a message to stisinfo@nsf.gov on the Internet, or call 703-306-1130 and ask for the STIS Flyer, publication No. 94–4.

Five-year Federal R&D outlook: frosty

That Government-sponsored R&D activities are undergoing a "wrenching process" is no secret, and at a recent IEEE-USA symposium Lionel S. Johns further divulged how the Clinton administration currently views Federal funding of R&D. As associate director for technology at the White House's Office of Science and Technology Policy, Johns coordinates technology policy among Federal agencies.

The five-year appropriations freeze to which the Administration agreed last year means a declining R&D budget in real terms, Johns said. Agencies face tough funding choices: NASA, for one, foresaw a $19 billion budget as programs matured, but must now make do with around $14 billion annually. A revamping of the space station design reduced NASA management from 1200 to 300 people, Johns said.

John A. Adam Washington Editor

Reflections

A bit is a bit is a bit?

Bits are everywhere these days. Piles of old floppy disks litter my workroom. I have no idea what is stored on them anymore, but I'm afraid to throw them out. I keep buying new floppies because it is easier than erasing the old ones.

I do the same with my hard drives. Every time I upgrade, I save the old drive somewhere. You never know when you'll need those old megabytes.

My living room and car are also becoming bit-dumping grounds. Hundreds of gigabits are stacked in neat little plastic packages containing audio compact disks. There are a lot that I never play anymore, but I can't throw them out after having paid so much money for them. They make nice trophies.

Now that my computer has gone multimedia, I am beginning to save CD ROMs. I believe that they contain fantastic material, but I have not actually had the time to confirm this belief. In any event, the disk jackets display marvelous pictures.

The sheer size of my bit archive impresses me. I can't wait until the telephone and television are digital and I am hooked into the information superhighway. Everything important in life will be simply an assortment of bits—voice, music, movies, data, and even money. My 1s and 0s will mirror my personality and worth.

The wonder of it all is that these bits are among the most anonymous, most elusive entities in the universe. Bits weigh nothing, occupy no space, obey no physical law, can be created spontaneously from nothingness, and can be endlessly replicated. Each in itself is the merest quantum of the Information Age, yet taken together all those little 1s and 0s are acting as if they were the most important force on the planet. And if you want indestructibility, then a bit is forever.

Unlike Humpty Dumpty in the analog world, bits can be restored to perfection. For example, if Michelangelo had had the foresight to digitize his painting in the Sistine Chapel, then we wouldn't be arguing today about what the colors are supposed to be. If Enrico Caruso's voice had been digitized, its echoes would resound unchanged today. When the world crumbles, the bits will still be there.

The Library of Congress is now beginning the task of digitizing its collection. Soon it will have the biggest pile of bits on the planet. On hearing of this plan, a questioner asked whether it would then be quite easy to rewrite history. For example, a simple global change command could be used to substitute "Eurasia" for "Oceania," so that Winston Smith's job in Orwell's *1984* would be a snap. Conversely, digital signatures and message integrity codes could

J. D. King

freeze the history bits in their pristine form, thereby protecting the biases of the original authors. If you want info-perpetuity, the bits will oblige.

Of course, the bits may be forever, but the medium in which they are recorded is quite a different matter. The physical world seldom deals in perpetuity. As a case in point, the 1970 U.S. census is recorded in a format that can be read by only two computers in the world. One is in Japan; the other is in the Smithsonian Museum. The physical recording medium and format come and go. The bits are still there, but they become inaccessible. Makes you appreciate paper.

When I reflect upon these malleable yet indestructible quanta of information, I sometimes remember fondly the simplistic world of physics that I studied in high school. Electrons, protons, and neutrons made up everything, and the world was modeled as a billiard table. "Eight ball in the corner pocket," I would say to myself while calculating some physical interaction.

Now the physical world is all muddled up. I read the other day that experimental evidence for the last quark had been achieved. I had not even known that one was missing, because I've lost count of all the strange particles that seem to exist these days. I lament the loss of that billiard table model, and this has set me to wondering about bits, too. Maybe they actually aren't so simple either. Maybe bits have associated or hidden properties, and are really made of smaller info-quarks.

I started musing about the hidden properties of bits after a meeting that brought together telecommunications people and content people. The content people make the bits, while the telecom people use the motto, "You call, we haul."

To a telecom person bits are identical. After all, a bit is a bit. With the digitization of media it doesn't matter whether a bit represents speech, data, or video; they're all the same. What could be different about one bit?

It turned out that the content people were angered at this attitude. They argued that all bits are not created equal. One content person pointed at another. "My bits are better than his bits," he shouted. "My bits are more valuable, more carefully crafted, and more individualized. His bits are misleading and poorly wrought. How dare you treat all bits as equal! Only a network-centrist telephonehead could take such a position."

Even in the network I have doubts about the equality of bits. At a switching node the bits compete to join queues. One bit raises its hand. "I know that I look like all those other bits," it says, "but I must get through. I'm part of a television picture, and if I don't arrive in exactly...[the bit checks its wristwatch] 3 milliseconds, then the picture will break up. This bit next to me... [the bit points disparagingly] is e-mail. It has all day for delivery. We're really quite different, you know."

To add to the confusion, neighboring bits will carry different prices. It will probably be like airline seats. Video bits will have to be cheap. If they are priced like voice bits, then no one will be able to afford video. Maybe there will be frequent flyer miles and weekend discounts for bits that qualify. So you see, bits really do have different personalities and different needs. Maybe they are in fact composed of info-quarks.

So is it true that a bit is a bit? I'm not sure, but whatever they may be, I sure have a lot of them!

Robert W. Lucky

L+25

A Quarter Century After the Apollo Landing

Dave Dooling,
Contributing Editor

July 16, 1969, 9:31:45 a.m., EDT
NASA Launch Control (Kennedy Space Center): 'T-minus 15 seconds....'

Time makes it too easy to remember only the great events of history and to forget the opportunities and pressures that made things possible or, perhaps, inevitable. Memories of Apollo often start with U.S. President John F. Kennedy, just four months after his inauguration, issuing a challenge he had not anticipated.

"Kennedy came into office without a space agenda," recounted John Logsdon, director of the Space Policy Institute at George Washington University, Washington, D.C., and author of *The Decision to Go to the Moon*. "He was inclined to find areas to cooperate with the Soviets, and directed NASA [National Aeronautics and Space Administration] and the State Department to find programs where we might cooperate." But several events closed the path toward cooperation while opening the road to the moon.

Before Kennedy's presidency, the Soviet Union had already chalked up stunning successes in space. It had been first into space with Sputnik 1 in 1957 and the first to the moon with the Luna 2 probe in 1959. And on April 12, 1961, Russian cosmonaut Yuri Gagarin made a single orbit of the earth.

In non-space arenas, too, the USSR had embarrassed the United States. In 1960, the Soviets had shot down Francis Gary Powers' U-2 spy plane over the Ural Mountains during a photographic mission. Then in mid-April 1961, a U.S.-backed attempt to topple Cuba's communist government failed in the Bay of Pigs invasion.

Public reaction to all those events, plus Kennedy's own forward-looking attitude, "convinced him that [the United States] had to win in an arena where the other side threw down the gauntlet," Logsdon said.

Kennedy did not immediately aim for the moon, but commanded in an April 20, 1961, memorandum: "Find me a space program which provides dramatic results in which we can win."

At Kennedy's direction, Vice President Lyndon B. Johnson, also chairman of the Space Council, solicited opinions from two military officers and Wernher von Braun, former chief designer of Germany's A-4 (V-2) rocket and then director of NASA's Marshall Space Flight Center in Huntsville, Ala. "We do not have a good chance of beating the Soviets to a manned 'laboratory in space,' " von Braun replied. However, "we have an excellent chance of beating the Soviets to the first landing of a crew on the Moon." Moreover, it would demonstrate to the world what then–Vice President Richard Nixon had tried to tell Soviet Premier Nikita Khrushchev during the Kitchen Debate in 1959: that U.S. industrial might was greater.

In the weeks leading to the moon-landing decision, advisors assured Kennedy that most of the technologies and industrial capacity were available. The key task would be to integrate them into a new system. It was, Logsdon recalled, "a cold-blooded decision" devoid of the passion that had fueled centuries of human aspiration to travel to other worlds.

Thus, on May 25, 1961, with only the 15-minute suborbital hop by astronaut Alan Shepard in the logbook, Kennedy confidently stood before a joint session of Congress and pronounced his famous challenge: "I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth. No single space project in this period will be more impressive to mankind, or more important for the long range exploration of space; and none will be so difficult or expensive to accomplish."

NASA

Eight years later, Kennedy's goal was achieved: on July 20, 1969, Apollo 11 astronauts Neil A. Armstrong and Edwin E. ("Buzz") Aldrin Jr. became the first humans to set foot on the moon—and then they, along with third crew member Michael Collins, were returned safely to the earth.

July 16, 1969, 9:31:48 a.m., EDT
Launch Control: 'Guidance is internal. 12, 11, 10, 9....'

The ancient yearning to go to the moon had just started to take physical form in the 1920s and '30s, when modern rocketry was born. In January 1939, before Europe fell into war, the *Journal of the British Interplanetary Society* released its design for a "Lunar Space-ship" and brashly proclaimed: "A voyage to the Moon is possible at this moment."

The crucial aspect of the British Interplanetary Society study was that it used technology then available, thus making part of the public believe that landing humans on the moon might indeed be possible right away. It asserted that "if but a fraction of the money thrown away on armaments had been devoted to this purpose, the lunar trip would be an historical fact by now."

In 1951, Wernher von Braun, then working in the United States, and several colleagues produced a grand plan for a three-ship, 50-man, six-week mission to the moon. In 1952, von Braun wrote a detailed article for *Collier's* magazine, and later collaborated with Walt Disney's studios on a "Tomorrowland" special, all to convince the public that the journey was possible.

Throughout the 1950s, all studies and proposals for manned lunar landings were highly conceptual. But after Sputnik 1, it was time to apply engineering reality. On Oct. 25, 1960, NASA awarded Martin Co., General Electric, and General Dynamics US $250 000 contracts to study Project Apollo, a proposed program for a manned spacecraft that would orbit the earth and, eventually, the moon. But President Dwight D. Eisenhower, whose administration focused primarily on national security aspects of space flight, saw no need to continue manned space flight beyond Project Mercury, and did not plan to fund Apollo.

July 16, 1969, 9:32:00 a.m., EDT
Launch Control: 'Ignition sequence starts, 6, 5, 4, 3, 2, 1, zero. All engines running. Liftoff.'

Of the three study contractors, General Electric Co.'s Missile and Space Vehicle Department in Philadelphia was the most forthcoming in dis-

While *IEEE Spectrum* style usually follows IEEE practice in employing SI or metric units, this article, in order to preserve historical authenticity, retains wherever appropriate the inch-pound units commonly used by the National Aeronautics and Space Administration at the time.

NASA

cussing its designs. At a 1961 American Astronautical Society conference, George Arthur, GE's manager of advanced manned space systems engineering, discussed an array of design options, many based on GE's entry vehicles for warheads and spy satellites.

"We are now at ■ point in our technological development where engineering problems in lunar vehicle design rather than broad concepts occupy much of the time and effort of the technical community," Arthur wrote in 1961. "Numerous studies and experimental work, both classified and unclassified, indicate clearly that manned flight to the moon is both feasible and practical. In addition it appears today that no technological breakthrough is required to accomplish this. What is required, however, is a logical progression of the engineering state of the art."

The three contractors' reports were delivered on May 15, 1961, just 10 days before Kennedy's speech. Everyone knew something was in the wind. Even though the contracts did not call for landing designs, each of the studies outlined a possible approach.

Ironically, none of the study contractors built any of the Apollo hardware. On Nov. 27, 1961, NASA's Source Evaluation Board gave highest ratings to Martin Co., Baltimore, Md., for those portions of the spacecraft that would carry the crew through everything but the lunar landing itself. The next day, top NASA managers overruled the board and picked North American Aviation Inc.'s Space Division in Seal Beach, Calif., on the basis of its X-15 rocketplane and military aircraft experience. GE was later selected ■■ the Apollo mission integration contractor. General Dynamics Corp.'s Astronautics Division in San Diego, Calif., had no direct role.

July 16, 1969, 12:16:16 p.m., EDT
(Mission elapsed time 2:44:16)

The Saturn V third stage fires a second time to send the crew to the moon.

APOLLO: *'Hey Houston, Apollo 11. This Saturn gave us a magnificent ride....It was beautiful.'*

For many years the chief concern had been the behemoth that would launch ■ mission to the moon. NASA described the kind of vehicle that would be needed when it outlined "Nova—A manned lunar rocket" at the 10th International Astronautical Congress in 1959, in London. Nova was to be 220 ft tall and 60 ft wide, and generate 9 million pounds of thrust at liftoff to send ■ two-man lander to the moon.

The actual trip, though, was achieved with a taller and slimmer vehicle, the Saturn V. Its lineage can be traced back through Russia's Konstantin Tsiolkovski, the United States' Robert Goddard, and Germany's A-4 team. Under U.S. Army sponsorship in the 1940s and '50s, the A-4 begat the Redstone and Jupiter ballistic missiles. Eight Jupiter engines topped by propellant tanks built with tools used to build Jupiter and Redstone tanks yielded the Saturn I rocket, derisively nicknamed "cluster's last stand" at ■ time when getting one liquid engine to work was a challenge.

But work they did, and that encouraged the Huntsville rocket team to develop a larger Saturn vehicle. This Saturn V was powered by a cluster of five of the Air Force's F-1 engines; started in the 1950s by North American Aviation's Rocketdyne Division in Canoga Park, Calif., each F-1 engine produced 1.5 million pounds of thrust, as much as the entire Saturn I. In 1960 the Saturn rocket programs became the core of the work done at NASA's Marshall Space Flight Center in Huntsville, Ala.

The Saturn V inspired countless stories that hinged on superlatives: with the Apollo spacecraft, it stood 365 ft tall and weighed 6.4 million pounds at launch. The S-IC first and S-II second stages were 33 ft in diameter, while the S-IVB third stage was 21.7 ft wide. In the S-IC first stage (built by Boeing Co.'s Launch Systems Branch, New Orleans, La.), five F-1 engines generated ■ record 7.65 million pounds of thrust for 2 minutes, 40 seconds. The F-1's intense yellow-white flame came from RP–1 (refined kerosene) and liquid oxygen propellant. The S-II second stage (built by North American Aviation) was powered by five Rocketdyne J-2 engines, which burned liquid hydrogen and liquid oxygen. The S-IVB third stage (built by Douglas Aircraft Co., Huntington Beach, Calif.) used one J-2 engine.

"Without excellent hydrogen engines, we could

First designer

"A voyage to the Moon is possible at this moment." The statement seemed brash when implied by President Kennedy and NASA in 1961, but it was more so in 1939, when it was published by the British Interplanetary Society, London, in its plans for a "Lunar Space-ship."

"The BIS Space-ship was the first design of its kind," said Arthur C. Clarke, interviewed by telephone from his home in Colombo, Sri Lanka. "It stands up well to Apollo 11." Clarke was a member of the BIS Technical Committee that designed the Lunar Space-ship long before his science fact and fiction writings helped persuade the public that the BIS was right.

The BIS Technical Committee was formed in February 1937 to show "how a vessel may be constructed to carry a crew of two [later three] safely to the Moon; permit their landing for a stay of 14 days; and provide for their safe return with a payload of half a ton." The committee limited itself to available technology and dedicated itself to extensive design work. Clarke, then 21 and a BIS member since 1935, calculated lunar trajectories.

Bantam

Arthur C. Clarke

The fruit of their labors, published in the *Journal of the British Interplanetary Society* in January and July 1939, would have stood 30 meters tall and 6 meters across, amassed 1.1 million kilograms, and used 2490 solid rocket motors fired by a complex wiring arrangement, similar to that of a telephone switchbank.

The requirements for liquid propellant pumps seemed impossible, but "we thought it could be done with solid rockets," Clarke said. The committee deduced that inertial navigation was needed and introduced the vertical landing concept, but admitted that landing legs were the weakest part of the design: "Any suggestions re the design of shock absorbers would be most welcome," it pleaded in the *Journal*.

In terms of public relations, the BIS Lunar Space-ship was highly successful: people from Australia to the United States had begun talking about the actual possibility of a manned voyage to the moon. Such discussions and articles, then and into the 1940s and '50s," prepared the public mind for it, so they knew it wasn't all Buck Rogers," Clarke noted.

The post–World War II era saw rocket studies expand in the wake of the capabilities demonstrated by the V-2 rocket. In a long 1946 lecture, "The Challenge of the Spaceship," later published as a book, Clarke predicted that the first guided missile would hit the moon around 1950 (it was 1959), but that chemical rockets would keep humans from making the trip until 1970. "Any chemically fueled spaceships will be unwieldy, fabulously expensive beasts with fuel consumptions measured by the thousand tons for a single voyage," Clarke wrote in the September 1946 issue of the *Journal of the British Interplanetary Society*. The Saturn V propellant load for Apollo 11 was triple that.

When men did first set foot on the moon in 1969, Clarke watched from the CBS television studio at Kennedy Space Center in Florida, where he helped news commentator Walter Cronkite cover the event.

Still ahead of what the rest of the world considers probable or possible, Clarke feels that lunar travel might be made easier by the discovery, through NASA's Clementine lunar orbiter, of large quantities of water ice at the moon's south pole, which would be a source of cryogenic hydrogen and oxygen for propellant. South polar ice mines revolutionized the economy of the moon in *The Hammer of God*, Clarke's 1993 novel (Bantam, New York) about mankind struggling to divert a comet on a collision course with the earth.

This month, Clarke will have as his house guest George Mueller, the NASA associate administrator for manned space flight during Apollo; the two will watch as comet Shoemaker-Levy 9 collides with Jupiter on July 16—the 25th anniversary of the launch of Apollo 11.

not have made it," said Ernst Stuhlinger, former associate director at Marshall Space Flight Center and a member of the A-4 team. Von Braun had considered hydrogen too dangerous; research had started only in 1956, and the first practical engine did not fire until November 1961. But Abe Silverstein, director of NASA's Lewis Research Center, Cleveland, Ohio, convinced von Braun that hydrogen engines could work. "Von Braun seized upon the possibility with enthusiasm," Stuhlinger continued.

While hydrogen solved the energy budget, it introduced new problems, including aluminum tanks that became porous when cooled to −253° C (20 degrees above absolute zero). Marshall got around that hitch, and also pioneered the heliarc welding that joined panels of the tanks with precision. The Saturn V's S-IC first stage alone had three-quarters of a mile of fusion welds.

The Saturn V achieved the right trajectory to the moon with a guidance system descended from the A-4's (V-2 rocket's) gas-film–bearing gyroscopes. These evolved into the ST-90 inertial platform used on the Army's Jupiter, and finally into the Saturn V's ST-124M. During first-stage ascent, it employed a simple tilt "at this time, this angle" scheme. Above the thick layers of atmosphere, both second and third stages used adaptive guidance that recomputed the best trajectory every second. All of the Saturn V's guidance system, computers, and major electronics were incorporated in a single Instrument Unit (built by IBM Federal Systems Division, Huntsville, Ala.) atop the S-IVB stage.

One of the keys to getting Apollo off the ground on time was the decision by NASA associate administrator George Mueller to do an "all up" unmanned test of the entire vehicle and spacecraft with the first Saturn V launch. "The Germans [at Marshall] couldn't believe it," said former deputy administrator Robert Seamans. "They were sure this was crazy."

Mueller's logic was direct and seductive. Marshall had planned a series of flight tests validating the first stage, then adding the second, then the third, and finally the spacecraft. Yet, to collect valid flight data, the upper stages had to be filled with liquid oxygen and hydrogen, not water. So as long as the tanks are filled, Mueller reasoned, why not have engines and fire them? And why not use a real spacecraft? Even if something fails, a lot can be learned just by getting everything to the pad.

The Marshall team bought the concept, and on Nov. 4, 1967, the first Saturn V—designated AS-501—boosted the unmanned Apollo 4 spacecraft high enough to reenter the atmosphere at speeds approaching a lunar return. It was a complete success and recouped more than a year of the work lost to various problems, including the January 1967 Apollo 1 fire that killed three astronauts.

Still, Marshall's conservatism paid off in other areas. The Saturn V's payload capability allowed the Apollo spacecraft to be 50 percent heavier than was originally planned.

July 17, 1969, 12:16:59 p.m., EDT
(Mission elapsed time 26:44:59)

The crew makes the first midcourse correction, slightly refining Apollo's trajectory toward the moon.

Once outside the earth's atmosphere, the spacecraft is subject to the gravitational effects not only of the earth but also of the moon and the sun; thus its orbit and trajectory are mathematically insoluble, because no simple equation can be written for three or more gravitationally interacting bodies moving through space. Again, the Cold War arms race provided technology for repeatedly recalculating the trajectory en route.

In the 1950s, Charles Stark Draper at the Massachusetts Institute of Technology's (MIT's)

Countdown to Apollo

1926, March 16	Robert Goddard launches first liquid-propellant rocket.
1939, January	British Interplanetary Society announces "Lunar Space-ship" design.
1942, June 13	First A-4 is launched (fielded in 1944 as V-2).
1951–52	Wernher von Braun and colleagues develop moonship concepts for *Collier's* magazine.
1953, February	Charles Stark Draper demonstrates Space Inertial Reference Equipment (Spire) on B-29 flight from Boston to Los Angeles.
1957, Oct. 4	Sputnik 1 is launched.
1958, Oct. 1	National Aeronautics and Space Administration (NASA) is formed.
1960, May 10	Nuclear submarine U.S.S. *Triton* completes first circumnavigation of the globe using Shipboard Inertial Navigation System (SINS), developed for ships carrying Jupiter ballistic missiles.
July 20	First submerged launch of Polaris ballistic missile is made from U.S.S. *George Washington;* the missile used the Mark II Inertial Measurement Unit, on which the Apollo Inertial Measurement Unit was based.
Sept. 13	NASA issues a request for proposals to study the feasibility of Project Apollo to orbit men around the earth and then the moon.
1961, April 12	Yuri Gagarin orbits the earth in Vostok 1.
May 25	U.S. President John F. Kennedy seeks commitment to a moon landing.
Oct. 27	First Saturn I is launched; at the time, it was the world's largest launch vehicle and it demonstrated clustered engines.
1962, July 5	Lunar Orbit Rendezvous is selected as Project Apollo's flight plan.
1964, Aug. 13	Central Committee commits the USSR to a manned moon landing.
1965, Dec. 15	Gemini 6 came within inches of Gemini 7 and matched velocity and position to orbit in formation around the earth, demonstrating the first space rendezvous.
1966, Feb. 2	The unmanned Luna 9 spacecraft hard-landed on the moon with the first television camera, which returned pictures of the surface for three days.
June 2	Surveyor I becomes the first spacecraft to make a soft landing on the moon, revealing that the lunar soil would indeed support an astronaut; it returned 11 237 photos over the next seven months.
1967, Jan. 27	Apollo 1 fire kills three astronauts.
April 23	Soyuz 1 flight ends in the death of one cosmonaut.
Nov. 4	The unmanned Apollo 4 spacecraft is carried into earth orbit in the first launch of a Saturn V, fully demonstrating the launch vehicle and Command/Service Module.
1968, Sept. 15–21	The unmanned Zond 5, which sent a variation of the manned Soyuz spacecraft around the moon and was recovered on the earth, was taken in the West to be a demonstration of the USSR's manned lunar program.
Oct. 11–22	Apollo 7, which tested all Command/Service Module systems in earth orbit for 10 days, becomes the first manned Apollo mission.
Dec. 21–27	Apollo 8, the first manned mission to orbit the moon, validates Apollo's guidance, navigation, and control system.
1969, Jan. 14–18	Soyuz 4 and Soyuz 5 rendezvous and dock in earth orbit, demonstrating crew transfer method for manned lunar mission.
Feb. 21	First Soviet N-1 rocket, designed for manned lunar missions, is destroyed 70 seconds after liftoff.
March 3–13	Apollo 9 tests the Lunar Module in earth orbit.
May 18–26	Apollo 10 demonstrates lunar landing mission down to 9 miles above the moon's surface.
July 20	Apollo 11 makes the first manned lunar landing.
1972, Dec. 7–19	Apollo 17 makes the sixth and last manned lunar landing.

Source: various NASA publications; *TRW Space Log*; Charles Stark Draper, *Inertial Guidance*

Instrumentation Laboratory in Cambridge developed an integrating computer called Spire (Space Inertial Reference Equipment) that determined speed and position, and demonstrated it aboard a B-29 bomber in a 1953 coast-to-coast flight. Further advances were made with the Navy's development of the Shipboard Inertial Navigation System (SINS) for ships carrying Jupiter missiles. On May 10, 1960, SINS was used in the nuclear submarine U.S.S. *Triton* to complete the first underwater circumnavigation of the globe. Draper's laboratory then developed a miniature version of SINS for the Navy's Polaris ballistic missile, which replaced the risky shipboard Jupiter ones. The Polaris Mark II inertial measurement unit became the heart of the Apollo guidance system.

The Mark II inertial measurement unit was a 12.5-inch sphere weighing 42.5 lb and enclosing three 2.5-inch diameter gyroscopes and three 1.6-inch diameter accelerometers (one for each axis, x, y, and z). The unit integrated the vehicle's motions to produce a net signal indicating how far it accelerated in what direction. But where Polaris was designed for a flight lasting a few minutes, Apollo had to operate for up to two weeks.

Norman Sears, former assistant Apollo manager at MIT, said that moving the inertial measurement unit from Polaris to Apollo "did not represent that great a challenge," though the team did have to extend the system's reliability. (It took three vendors to make gyro bearings that lasted, and extreme measures to ensure cleanliness of the brominated fluorocarbon in which the entire gyro floated.) Weight was shaved, and a sextant and a scanning telescope were added for navigational updates.

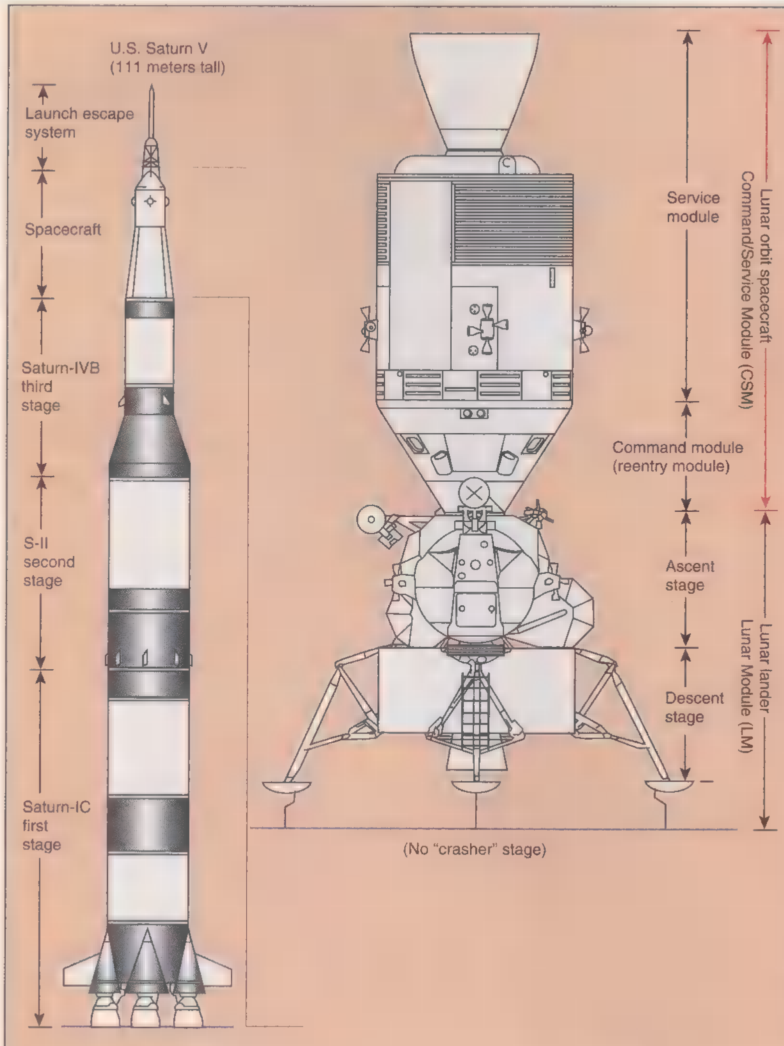
Still, not everyone was persuaded the system would work until designer Draper wrote Seamans to "volunteer for service as a crew member on the Apollo mission to the moon." He added: "Let me know what application blanks I should fill out."

July 20, 1969, 1:44:00 p.m., EDT
(Mission elapsed time 100:12:00)

In lunar orbit, the Eagle (the Lunar Module) undocks from the Columbia (the Command/Service Module).

EAGLE: 'The Eagle has wings.'

The original NASA contract that North American won was for most of the Apollo spacecraft: the cone-shaped Command Module (CM), in which the three astronauts would ride from liftoff to splashdown, and the Service Module (SM), which would carry fuel cells, control rockets, and other systems. A lunar landing stage for the entire Command/Service Module with all three astronauts was to be contracted for separately.



Source: NASA

What happened to the other runner?

Hours after Apollo 11 landed, the USSR's unmanned Luna 15 soil sampler crashed onto the moon. In the years following, the Soviets claimed they had never been in a race to the moon—until *glasnost* loosened restrictions, the USSR fell, and Soviet space program memoirs and artifacts went on the block at Sotheby's in late 1993. The newly available documents showed that, indeed, the Soviets had been in a moon race and fell by the wayside. With such a head start, how did they lose?

"Simple—Korolev died too soon," said James Oberg, a Houston-area space engineer and long-time observer of the Soviet/Russian space program. (In 1974 he won the National Space Club's Goddard History Essay Award for "Russia Meant to Win the Space Race.")

In fact, the USSR's problems were more extensive than the loss of Sergei Korolev, the chief designer of Rocket Cosmic Systems, whose identity was kept secret until his death in 1966. "Their space program was hopelessly inefficient, counterproductive," Oberg continued. Everyone's efforts went into currying favor with those who could make arbitrary decisions, he contended. "The Soviets were so enmeshed in their own delusions that they had no feedback loop or concept of success beyond [international] headlines."

First, headlines were made by the SS-9 Sapwood missile. Its 1957 launch of Sputnik 1 was meant to demonstrate that the Soviets could put a nuclear warhead anywhere. But neither Eisenhower nor Khrushchev anticipated the public reaction to the first artificial satellite.

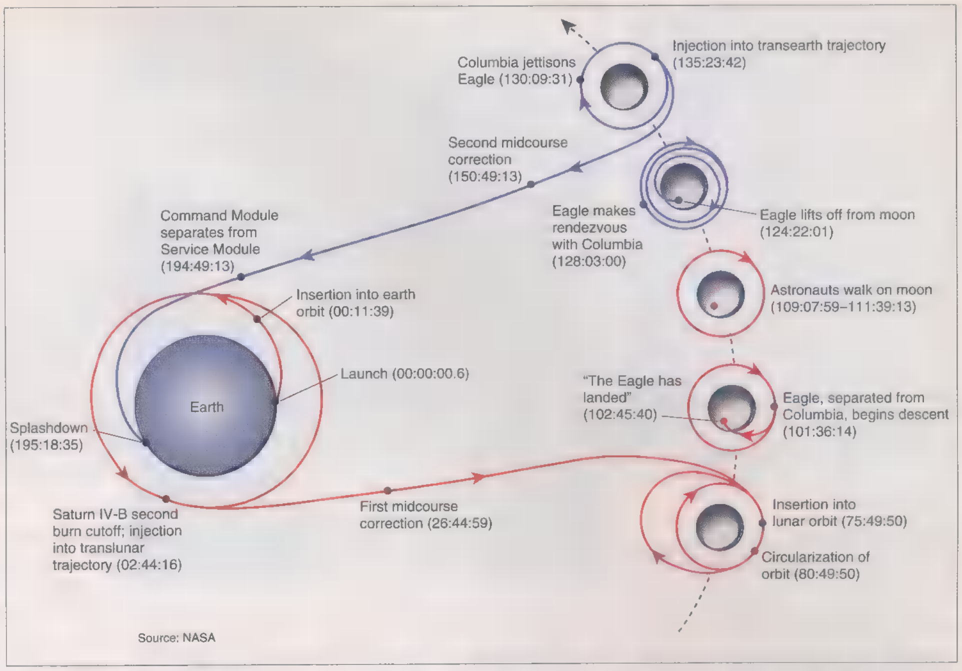
Having thus instigated a space race, the Soviets adopted a strategy of picking U.S. goals they could achieve and bypassing the rest, Oberg explained. The strategy succeeded for a few years. The "last first" of significance was the landing of Luna 9 on Feb. 2, 1966. Two months earlier, the U.S. mission where Gemini 6 and Gemini 7 maneuvered to within inches of each other in earth orbit had demonstrated rendezvous, which would be needed for a lunar mission.

By that time, the Soviets had realized that Kennedy's decision to go to the moon had not died with him: the United States was cutting metal and flying Saturn rockets. Belatedly, on Aug. 3, 1964, the Central Committee of the Communist Party made the moon the official target of the USSR. But the Soviets lacked the teamwork to keep up with the United States. "Because they knew everything could be flopped [by a political power shift], energy was poured into achieving

Such ■ design could serve two schemes for getting to the moon: Direct Ascent (launching straight from the earth for ■ direct landing on the moon) and Earth Orbit Rendezvous (going first into orbit around the earth to assemble the spacecraft that would then head for the moon).

That configuration fit what everyone expected. And that worried John Houbolt, ■ dynamics engineer at NASA's Langley Research Center in Hampton, Va. "I said, 'That's brute force,'" Houbolt recounted. "Intuitively I felt that's not the way to do it." Thus started ■ battle to get a fair hearing for the Lunar Orbit Rendezvous concept: putting the Apollo spacecraft into lunar orbit and then dropping only a small lander carrying one or at most two astronauts and designed solely for the trip to the surface and back to rendezvous with the rest of the spacecraft in lunar orbit.

Four options had been available for the moon trip. Besides Direct



The Apollo 11 mission to the moon lasted just over eight days (195 hours, 18 minutes, 35 seconds). The Saturn V carrying Apollo lifted off from NASA's Kennedy Space Center in Florida on July 16, 1969. The Lunar Module Eagle landed on the moon on July 20. The Command Module splashed down in the Pacific Ocean on July 24.

the desired decisions instead of organizing a team," Oberg said.

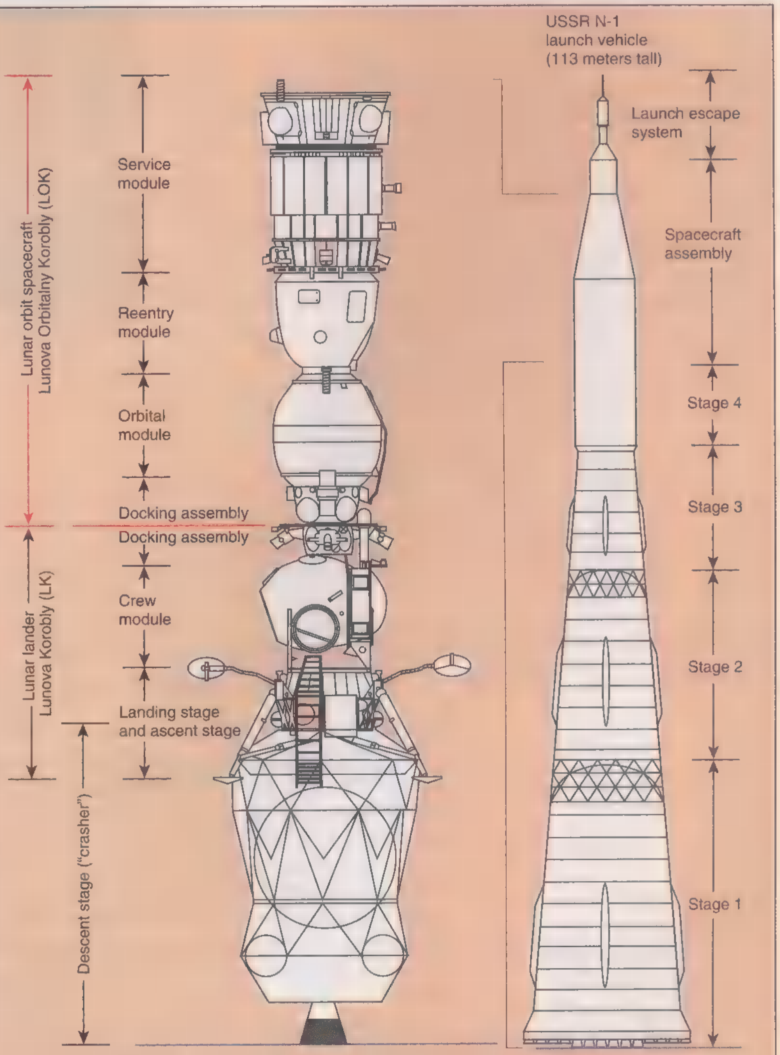
Perhaps the greatest shortcoming was Valentin Glushko's refusal to participate when Korolev won the lead role. Glushko denied Korolev's team access to valuable engine designers and test stands. As a result, their N-1 moon rocket was never fully tested before its first launch.

The N-1 was almost 17 meters wide (10 meters for the Saturn V) and 110 meters tall, including spacecraft (compared with 111 meters for the Saturn V). The N-1's 30 first-stage engines would generate 10.2 million pounds of thrust (the Saturn V generated 7.8 million pounds). It was topped by a two-man Lunova Orbitalny Korobly (LOK) lunar orbiter, based on the manned Soyuz spacecraft, and the one-man Lunova Korobly (LK) lunar lander.

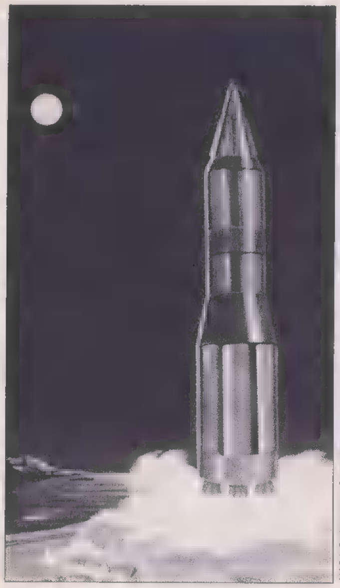
Once in lunar orbit, a cosmonaut would board the LK by spacewalk. Using the "lunar crasher" approach, the stage that injected the two spacecraft into lunar orbit would also slow the LK to within 2 km of the lunar surface and then be dropped, giving the LK another minute to make the final approach with its own engine. After a brief exploration of the surface, the cosmonaut would return in the LK to the LOK, again using the landing engine (a backup was provided). Although all the elements of the system were tested under the all-purpose Cosmos and Zond designations, neither the spacecraft nor the N-1 launcher proved reliable or durable.

The N-1 "was a pile of rockets built by various agencies [that] designed in isolation" from each other, Oberg noted. The N-1 booster blew up during its first launch—the first time its entire first stage had fired—on Feb. 21, 1969. "The cosmonauts were bitterly disappointed," Oberg said, "but it's just as well that no one had to bet their life on it.... They privately said they were relieved." Although Oberg is convinced that "the Russians would probably have been able to make it work, eventually," eventually never came. After the fourth and last N-1 failure on Nov. 23, 1972, the Soviets gave up and focused on the Salyut and Mir series of space stations, leaving Oberg and others to dig like archaeologists for the truth about the moon race.

Oberg and his then-fiancée (now wife) Alcestis, a writer, were both students at Northwestern University in Evanston, Ill., in the summer of Apollo 11. They watched the launch between classes and, for the moon walk, set up a viewing center in the faculty lounge with TV sets borrowed from local dealers. All who crowded into the lounge were silent through the first half hour until Aldrin moved the camera to view the Lunar Module—and the room burst into applause.



Source: Dick Gautheir in *Astronautics & Aeronautics* and *Aviation Week & Space Technology* (N-1); Charles P. Vick, *Aviation Week & Space Technology* and *Spaceflight;* Luc van der Abeelen (LOK/LK)



NASA/Smithsonian Collection

The Nova launch vehicle, proposed in 1959, was NASA's first design for boosting a two-man lunar lander. It would have generated 9 million pounds of thrust.

NASA/Massachusetts Institute of Technology

Engineers from Massachusetts Institute of Technology and Sperry Gyroscope Co. place a pendulum accelerometer inside an inertial measurement unit that guided Apollo 11 to the moon. The Command/Service Module and Lunar Module had identical units.

Von Braun's moonomania

Dave Dooling

Ernst Stuhlinger

"Von Braun began planning for Apollo when he was 14 or 15 years old," recalled Ernst Stuhlinger, one of von Braun's closest aides and his associate director at NASA's Marshall Space Flight Center in Huntsville, Ala., in the 1960s. "At that early age, von Braun realized that to go to the moon and Mars, one primarily needs a transportation system. So he decided that he would first of all build powerful precision rockets."

But where others could envision the technical requirements of rockets, von Braun could in addition envision the organizational requirements and public support that were equally necessary to turn the vision into reality. He had a most disarming approach that won over the President and later NASA, Stuhlinger recollected. "Von Braun could always say, 'Well, gentlemen, if you would like to go to the moon, I am ready to build the rocket for you. I happen to have the team which can do it.... the shops, the machines, the research laboratories, the development facilities. I can do it.'"

And do it he did. Right after the USSR's launch of Sputnik 1 stunned the United States in 1957, von Braun promised U.S. Secretary of Defense designate Neil McElroy that his team would orbit a U.S. satellite within 60 days (his boss had him back off to 90 days; von Braun did it in 89). Less than four years later, when President John F. Kennedy made his commitment to send Americans to the moon, von Braun promised he would also make that happen.

"He could just influence people with a magnetic force," Stuhlinger continued. "Those who worked for him felt privileged to do so." Indeed, much of von Braun's rocket team followed him from Peenemunde, Germany, to Fort Bliss, Texas, and then to Huntsville. When the team's efforts culminated in Apollo 11, Stuhlinger was at the Kennedy Space Center VIP viewing area, escorting Hermann Oberth, whose 1923 book, *The Rocket into Planetary Space,* had helped inspire von Braun's quest.

Ascent and Earth Orbit Rendezvous, Lunar Orbit Rendezvous and Lunar Surface Rendezvous were considered. The principal tradeoff among them was between launch vehicle and spacecraft: simplifying one of them complicated the other.

Lunar Surface Rendezvous could make do with the relatively small Saturn I rocket, but it involved placing at least three spacecraft on the moon's surface where robots would assemble the return vehicle. Then the astronauts would be dispatched to the moon in a fourth craft. Lunar Orbit Rendezvous could use the huge Saturn V, but required two spacecraft: one in orbit around the moon and the other going to the moon's surface and then back up again to the orbiting spacecraft. NASA management had decided that Apollo's complexities were best handled close to home, and rejected both forms of lunar rendezvous.

Direct Ascent required a Nova-sized booster to launch the entire spacecraft straight from the earth all the way to the moon without assembly operations in orbit. Earth Orbit Rendezvous, on the other hand, required two Saturn V rockets to boost payloads into earth orbit: one to launch the spacecraft and escape stage, and the other to launch a tanker to refuel the escape stage.

Earth Orbit Rendezvous was favored by von Braun for its role in Mars expeditions and by Jerome Weisner (Kennedy's science advisor) and the Department of Defense for its impact on military missions. Furthermore, everyone considered that building the immense Nova was too great a task, whereas the Saturn V seemed achievable within the budget and schedule.

But both Direct Ascent and Earth Orbit Rendezvous required a lander 70 to 90 ft tall and up to 21 ft wide—larger than an Atlas ballistic missile. The crew would have to fly blind as they made their final descent to the lunar surface, and then would have to clamber down the side of the lander, which would be top-heavy after consuming propellant in its lower stage.

Even after NASA officially selected Earth Orbit Rendezvous for the Apollo program, Houbolt continued to promote Lunar Orbit Rendezvous. He calculated it would cut the total spacecraft weight from 130 000 lb to 62 800 lb, including a 19 320-lb lander; furthermore, his numbers showed that it would require just one Saturn V launch. But few people believed him. At a May 1961 meeting, a key manned space official told Houbolt, "Your figures lie," and at another meeting in July he was ordered not to discuss Lunar Orbit Rendezvous.

The following November, Houbolt went outside organizational channels and wrote what he now realizes was "one of those letters that change history." As a "voice crying out in the wilderness," he appealed to NASA deputy administrator Seamans, who called for a more even-handed assessment. Meanwhile, key leaders in Langley's Space Task Group (soon to move to Houston and become the Manned Spacecraft Center) began to realize what Houbolt had sensed from the beginning.

NASA contracted with Vought Astronautics Co. in Dallas, Texas, to be an independent referee and to reevaluate all the approaches. The answer came back strongly in favor of a rendezvous in lunar orbit. Finally, Marshall director von Braun stunned everyone by announcing that Lunar Orbit Rendezvous was indeed the best way to go. On July 5, 1962, NASA announced that Apollo was changing gears, and in November it named Grumman Aircraft Engineering Co., Bethpage, N.Y., to build the Lunar Excursion Module (later, the name was shortened to just Lunar Module or LM) with descent and ascent stages and room for two men.

This left North American to handle just the Command/Service Module (CSM) combination that would carry the crew through everything but the lunar landing. Where possible, the CSM and LM used identical technologies or systems, such as the inertial measurement unit and main computer.

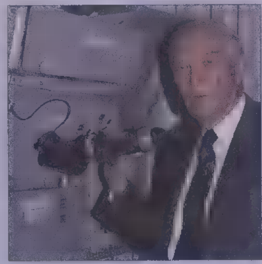
Although its contract came late, Grumman already had a head start. "Grumman was very smart,"

Pushing through ignorance

Stashing a million-dollar guidance system in a refrigerator is not in the textbooks, but that is what Norman Sears and his crew did to assure the Apollo 13 astronauts that their guidance system would work when it was reawakened from the cold for the emergency return to earth.

Sears, former Apollo manager at the Massachusetts Institute of Technology's Instrumentation Laboratory (now the Charles Stark Draper Laboratories), said each mission had its own personality. "We were stretched thin for years. We were never making 'minor' modifications until we reached Apollo 15" in 1971.

Sears remembers how his staff was pressed to the limit on at least three times. Apollo 11 had computer overload alarms on its final approach. On Apollo 13, an explosion left the spacecraft without power; the crew huddled in the Lunar Module for three long days before reentering the earth's atmosphere in the Command Module with nearly frozen systems. Then on Apollo 14, a bad switch would have aborted a lunar landing as soon as it began. "We actually developed a program to ignore the switch," Sears recalled. "We tested it, shipped it to Houston [over the telephone wires], and uplinked it to the LM." In 1969–71, that was "gutsy stuff."


Dave Dooling

Norman Sears

In Sears's view, one of the chief byproducts of Apollo was the experience with computer software—programming, verifying code, and testing it under simulated conditions. Once launched, each of the Apollo missions "had to work the first time," he pointed out. "It surprised a lot of us that the simulations were so good."

Sears noted that the team had the advantage of not knowing in advance that some things are impossible. "In our ignorance," he said, "we plowed ahead and had the momentum to press through."

recalled Arthur. "About halfway through [the Apollo feasibility study] they saw that Direct Ascent was not good" and started examining a lander concept. GE's Apollo feasibility study had included a large appendix by Grumman, its study teammate, detailing what would be needed to send a spacecraft to the moon's surface, and Grumman had continued to study the LM on its own.

"Somehow, we collectively decided it would be a good thing to put together an appendix on the whole mission" to the moon, said Tom Kelly, LM chief engineer at Grumman and widely acknowledged to be the father of the module. "We took the LOR [Lunar Orbit Rendezvous] approach and it looked good to us" and even to team members who studied the other approaches.

Houbolt's numbers would turn out to be low. Apollo 11 weighed 100 698 lb at translunar injection, and the LM weighed 33 297 lb—but the concept was literally on target.

The cheapest way to the moon

Dave Dooling

John Houbolt

Engineers are not known for writing best-sellers, but John Houbolt did just that in 1961 with "Manned Lunar Landing via Rendezvous." The 50-page report in two slim volumes documented calculations that many in NASA were ignoring. They suggested that dropping a specialized lander from a spacecraft in lunar orbit and then returning it to rendezvous with the orbiter before heading back to the earth was the cheapest way to do a moon landing with just one launch vehicle. The report, which included contributions from Houbolt's rendezvous study team, gave "the whole picture," its author said. "One hundred sets were gone in a day." Its circulation within NASA helped swing the tide in favor of Lunar Orbit Rendezvous.

One key finding was that "a great big lander was not required," Houbolt said. He and his team conceived of a vehicle that would have two economy-style landers, with the astronaut sitting on an open metal platform and using a plum bob and stopwatch for his guidance system. Soon Houbolt was asking NASA, "Why buy a Cadillac?"

Ironically, Houbolt did not get the word directly from NASA that his work had carried the day. He was in Paris in July 1962, and a friend saw an article on NASA's change of approach in the *International Herald Tribune*. Handing him the paper, Houbolt's friend said, "I can safely say I'm shaking hands with the man who single-handedly saved the government $25 billion."

Houbolt watched the Apollo 11 launch at the Kennedy Space Center and the splashdown on July 24 from Mission Control in Houston. One of the many items that the Apollo 11 crew carried to the moon and back now hangs in Houbolt's office—one of his original Lunar Orbit Rendezvous drawings.

July 20, 1969, 4:10:00 p.m., EDT
(Mission elapsed time 102:38:00)

Five minutes into the Eagle's powered descent to the moon's surface, an alarm sounds.

EAGLE: '1202, 1202....Give us the reading on the 1202 program alarm.'

NASA MISSION CONTROL, MANNED SPACECRAFT CENTER, HOUSTON: 'Roger. We got—we're go on that alarm.'

About 3 minutes before landing on the moon, the first of five different computer alarms rang, catching both astronauts unaware. Flight directors knew from telemetry and tracking that the Eagle was okay, and told the crew to press onward (the problem was rendezvous radar data overflowing the computer).

In the movies, landing a rocket had been as simple as running the film backward. But NASA had recognized from the start that in reality the crew would need a computer and autopilot software to "fly by wire" and maneuver over unsuitable terrain to the touchdown point, and to trim rocket thrust as propellant was consumed.

"The computer was the one item that required a lot of development," said former assistant Apollo manager Sears. "It sounds ridiculous now, but it was a challenge to make it powerful enough to handle the mission onboard without help from Mission Control." In addition, the computer needed unprecedented reliability.

Columbia and Eagle shared a common computer design with spec numbers that seem staggering in this age of notebook and palmtop computers: the Apollo computer measured 6 by 12 by 24 inches, weighed 70.1 lb, and drew 70 W at 28 V dc.

Within that bulk was a memory holding only 36 864 words of 15 bits each in ferrite core rope memory, and 2048 words in a rewriteable coincident core memory. A magnetic field was impressed on ferrite core rings as they cooled in an oven, and software became hardware as the rings were threaded on copper wire matrices. This type of memory made today's familiar software patches almost impossible, but the Apollo programming was as sturdy as the computer. The computer also incorporated some of the first ICs, which were just becoming available following the Air Force's investment in the technology in the late 1950s.

"Verifying the code was a new experience," Sears said, and paring the software to fit the computer's 36-kB memory was a challenge. "By the time the mission flew, we had several 'Black Fridays.' " The man-machine interfaces—a simple keypad and four one-line digital displays—were not as elaborate as technology then allowed, but

still were new for the astronauts who were, at heart, test pilots. "They were used to dials," Sears said. "This was a whole new world for them."

The software had three main sections: the attitude state vector, the reaction control system laws, and the thrust vector control laws. Each computation cycle took 0.025 second and velocity updates were taken every 2 seconds from the inertial measurement unit. The positions of the two hand controllers were sampled every 0.00125 second. One proof of the computer's sophistication came when sloshing fuel wobbled the Eagle. The autopilot dampened that by firing the thrusters automatically in bursts as short as 0.014 second.

Although flying the LM has been likened to flying a helicopter, it was more complex. After a long face-up slide toward the landing zone, the LM would pitch upright for the final approach at a range of 2000 ft and an altitude of 500 ft. The spacecraft was moving at 58 ft/s forward and sinking at 15 ft/s. The crew had less than 4 minutes to land or abort the mission, and hovering was a most extravagant use of propellant. Like one of Zeno's paradoxes, the closer they got to the surface, the slower they had to go.

Finally, horizontal positioning required a great deal of piloting skill because the autopilot did not fully eliminate motion across the surface. "But once Neil [commander Neil A. Armstrong] took over, it was up to him, through changing attitude control, to null out those translation rates," recalled LM pilot Edwin E. Aldrin on the 20th anniversary of the landing. "And that's a significant increase in the talent level needed, and he was certainly up to it."

He had to be. "The auto targeting was taking us right into a...football field-sized crater, with a large number of big boulders and rocks," Armstrong reported a few minutes after touchdown. It required "flying manually over the rock field to find a reasonably good area" about 0.6 mile south and 3.3 miles east of their target.

In fact, the landing went so well that Sears said he almost thought it was just another simulation until he heard Aldrin say something not heard in training....

July 20, 1969, 4:14:00 p.m., EDT (Mission elapsed time 102:42:00)

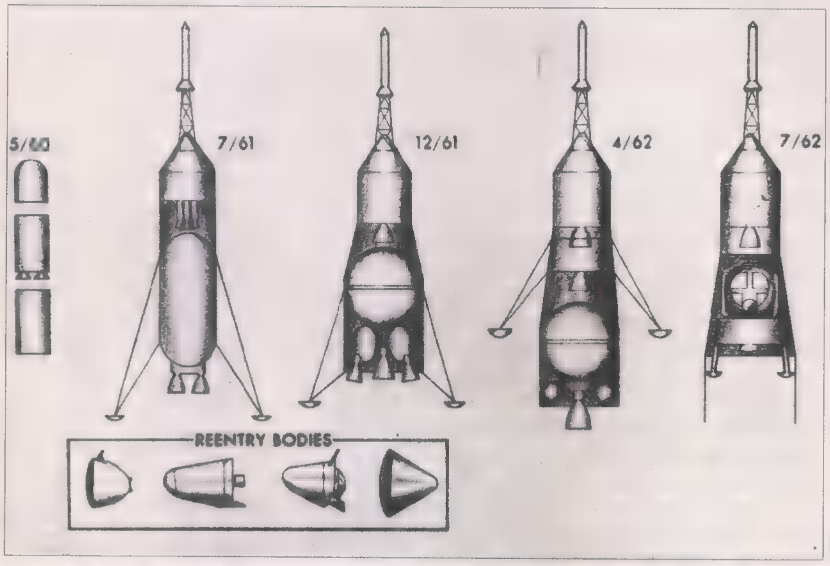
EAGLE: 'Lights on. Down 2-1/2. Forward. Forward. Good. 40 feet, down 2-1/2. Picking up some dust.'

For years, lander designers had been stumped by the problem of the crew members' limited ability to see just where they were going. With Earth Orbit Rendezvous, the best anyone could do was to give the astronauts two periscopes that were unlikely to win support from pilots used to eyeballing their way through a landing. The advice given by NASA's Houbolt, to build a specialized lander for Lunar Orbit Rendezvous, solved part of the problem. With the earth-return elements no longer involved in the lunar landing, the lander's cabin could be designed to look forward.

Still, the designers' minds were earthbound. Grumman proposed a large helicopter-style cabin to give the crew a clear view of the final approach as they sat on bar stools. But the panoramic windows were a problem: Plexiglas turns purple and brittle under solar ultraviolet radiation, while glass weighs too much and poses structural problems—and with either, the sunlight flooding through the windows would overload the environmental system.

In a now-famous case of serendipitous engineering, the separate problems were solved together. "Early in the preliminary design [1963], we were convinced that we didn't need the bar stools; they would be in the way," Grumman's Kelly said. Even with the engines at full thrust, the crew experienced less than 1 earth-gravity acceleration. "Simultaneously, we realized we wanted to minimize the glass area....We very quickly saw that with the crew standing up, you could get by with small pieces of glass."

So, the lander's cabin became a cylinder with small triangular windows little bigger than the astronauts' faces. The field of view now extended



Evolution of the Apollo spacecraft is shown in five early drawings: 5/60 (May 1960) is the initial NASA concept before the Apollo feasibility studies; 7/61 is the design that included a five-legged lunar lander; 12/61 shows how the lander was enhanced with a larger liquid-propellant descent stage; 4/62 shows the addition of a "lunar crasher" stage that would be discarded just before landing; 7/62 shows the final design of a Command/Service Module separate from the Lunar Lander. Reentry bodies were the leading candidates from the 1960–61 studies for the space capsule's descent into the earth's atmosphere.

Technicians for Raytheon Co.'s Space and Information Systems Division's laboratory at Sudbury, Mass., literally sewed fine copper wire to create the rope memory for the computer program in Apollo 11's onboard computer, which was designed by the Massachusetts Institute of Technology in Cambridge. Both the Command/Service Module and the Lunar Module used Raytheon computers for guidance, navigation, and control, each had six such rope-memory modules. Each module comprised 512 ferrite cores totaling what today would be called a 36-kB memory.

Father of the Lunar Module

After the Eagle—Apollo 11's Lunar Module (LM)—had landed on the moon, liquid helium in the pressurization system of the descent stage froze and formed a slug of hydrazine in a fuel line. Heat soaked back from the engine, and the pressure in the fuel line was rising ominously. Ultimately, the hydrazine would detonate.

Dave Dooling

Thomas J. Kelly

"It was one case where you decide right there, in the spacecraft analysis room, in real time," what must be done, recalled Thomas J. Kelly, who was chief engineer for the Lunar Module at Grumman Corp. in Bethpage, N.Y. During "a fairly intense few minutes" in which he and his colleagues decided it was necessary to "burp" the engine, "the ice plug melted and relieved the pressure and the problem went away."

Because the LM was dormant until landing, Kelly could see the launch from the Kennedy Space Center in Florida, then fly to Houston to monitor activities in the spacecraft analysis room next to Mission Control.

Grumman had ample opportunity to learn the technical and managerial lessons that made possible that kind of real-time call. "We set up a flight test center at Calverton [Long Island] that did for aircraft testing what we had learned from Apollo," Kelly said. It "improved the productivity of aircraft flight tests by a factor of three."

In an era of space gypsies, Kelly was unusual in spending virtually his entire career with one company. He was with Grumman in the late 1950s when it decided to go into space. Kelly helped lead the LM proposal, was project engineer, and stayed at Grumman through the recently ended space station support contract.

Risk analysis, also pioneered by Apollo, was a factor in shutting down Apollo. "You could argue for one or two more flights," Kelly said, "but there's a lot to be said for quitting while you were ahead."

all the way from the horizon straight down toward the moon's surface. The final design was in place by October 1964, when Grumman's plans and the M-5 (fifth engineering mockup of the LM) passed close scrutiny by NASA.

More detailed challenges still faced the LM team, not the least of which was weight. Every pound returned from the moon's surface to lunar orbit added 4.25 lb to the spacecraft because more propellant was needed to move it. A weight-reduction program shaved around 2500 lb at a cost of about US $10 000/lb. Savings were realized by chemically milling the crew module to just 0.012-inch thick and installing an electrical system that used fragile 26-gage wire (0.016 inch thick), miniature connectors, and new wire-wrap terminals. In addition, silver-zinc batteries were pushed to 2.5 Ah/lb, and then were watched closely because of their inherent explosive danger. Grumman also had to install three propulsion systems in the LM: a throttleable engine for landing, an ultrareliable engine for ascent to orbit, and 16 attitude thrusters.

July 20, 1969, 4:17:40 p.m., EDT
(Mission elapsed time 102:45:40)

EAGLE: 'Contact light. Okay, engine stop. ACA out of detent. Modes control both auto, descent engine command override, off. Engine arm, off. 413 is in.'
HOUSTON: 'We copy you down, Eagle.'
EAGLE (ARMSTRONG): 'Houston, Tranquility Base here. The Eagle has landed.'

Von Braun turned around to Houbolt, made the O.K. sign by circling thumb and forefinger, and said, "Thank you, John." But the last few inches had also proved to be the toughest for designers. Even through the Direct Ascent design in 1962, no one had addressed the full range of wobble, wiggle, and slide that the lander might manifest at the moment of touchdown.

To resolve the problem, NASA's Langley center, Grumman, and Bendix Corp. of South Bend, Ind., conducted hundreds of drop tests with models ranging from a miniature aluminum block measuring 3 by 3 by 4.5 inches with spikes for feet onto a lead surface, to 1/10-scale LMs landing on sand, salt, and aluminum oxide powder. The tests were run at different angles, heights, and orientations.

One finding was that landing on soil was the most hazardous because the spacecraft could plane after impact. Another was that four legs for the Lunar Module were as good as the five that Grumman had first proposed to increase stability. As the LM design matured, a full-scale model equipped with preproduction landing gear was suspended under a gantry and dropped sideways onto a wood platform to simulate lunar gravity.

Engineers realized early that each leg needed an inverted tripod with the vertex on the footpad, which was itself set on a ball-and-socket joint. Studies showed that after touchdown, the vehicle was still somewhat unstable, so designers added outrigger struts. Inside those struts and the main landing gear strut was honeycombed aluminum to absorb the final impact.

Even the design of the landing pads themselves was of great concern. Engineers at first assumed that the lunar surface would be rocklike and designed pads about 8.7 inches across. Then Thomas Gold, an astronomer at Columbia University in New York City, claimed that the surface might be a deep blanket of dust that would swallow spacecraft and astronaut. Grumman gave the LM the equivalent of snow shoes by widening the pads to 36 inches. The question was resolved when Surveyor 1 safely landed in 1966; its landing pads deliberately had been sized to exert more force than the LM or an astronaut.

As matters turned out, the LM's legs were generously overdesigned. The astronauts landed the LM "like a crate of eggs," Grumman's Tom Kelly said, at less than 2 ft/s. Engineers later calculated that the lunar surface had absorbed some 60 percent of the impact.

July 20, 1969, 4:30:30 p.m., EDT
(Mission elapsed time 102:58:30)

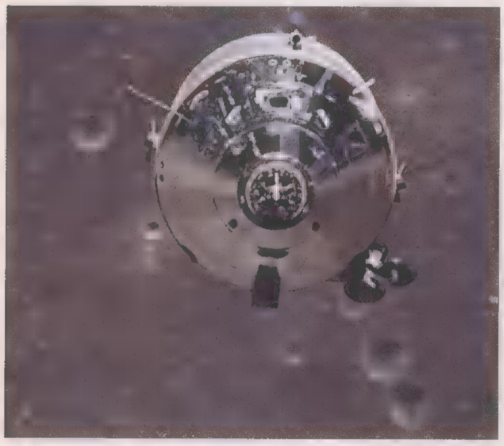
HOUSTON: 'Rog, that was a beautiful job, you guys.'
COLUMBIA: 'And don't forget one in the command module.'

But the world does tend to forget that Apollo was two spacecraft: the lander plus the Command/Service Module Columbia, which remained in lunar orbit. In essence, the Columbia was a reentry capsule—the Command Module (CM)—attached to a utility van—the Service Module (SM). The fuel cells in the SM and the heat shield on the CM were identified as two big technical breakthroughs by N.J. Ryker, Apollo Vehicle Systems Director for North American, in a May 1964 American Astronautical Society paper.

NASA

"The Eagle has wings." The Apollo 11 Lunar Module Eagle gets a visual inspection from astronaut Michael Collins in the Command/Service Module Columbia shortly after the two craft separated in lunar orbit (the lander rose away from the moon, which is why the sky is the black of outer space). The landing gear consisted of four outrigger struts, each filled with aluminum honeycomb and internal pistons to absorb the impact of the lunar landing. The probes pointing down beneath three of the four landing pads carried surface-contact buttons that illuminated a contact light in the lander, telling commander Neil A. Armstrong that the Eagle had touched the surface and it was time for him to shut down the descent engine. The forward leg had no probe lest it curl upward at landing and obstruct the astronauts as they descended the ladder.

Edwin E. ("Buzz") Aldrin Jr. examines the probe projecting from the pad of the Eagle's starboard landing gear, which experience showed was overdesigned. On Apollo 11, the primary struts [large diagonal strut in the photo] showed virtually no compression; the secondary internal piston in the struts [horizontal strut] stroked less than 4 inches.



Columbia is seen above the moon's Sea of Fertility from the Eagle as it rose away from the Command/Service Module during the separation maneuver in lunar orbit on July 19. Columbia, which remained in lunar orbit with astronaut Mike Collins, was coated in silverized Teflon to insulate it from the sun's radiant energy.

The bulk of the SM was taken up by the Service Propulsion System, which comprised two pairs of fuel and oxidizer tanks and an engine with a nozzle larger than the Mercury capsules. The Service Propulsion System braked the entire Apollo spacecraft into lunar orbit. After the two astronauts returned from the lunar surface to the Columbia and jettisoned the Eagle, the SM boosted the Columbia out of lunar orbit and back to the earth.

For the Service Propulsion System, the Lunar Module's descent and ascent propulsion systems, and both vehicles' attitude thrusters, NASA traded the high energy of cryogenic propellants for the high reliability of hypergolics, chemical compounds that ignite on contact. Although hypergolics—in this case, nitrogen tetroxide and a mix of hydrazine compounds—are highly corrosive and toxic, they require less insulation than liquid oxygen or hydrogen.

The Service Propulsion System tanks occupied four of six radial sectors in the cylindrical SM. The fifth held the fuel cell system with four small cryogenic tanks, two each of liquid oxygen and liquid hydrogen. The cryogenics were combined in three fuel cell power plants to produce the electric power needed to run the spacecraft, issuing drinking water as a byproduct. Each power plant was a stack of 31 fuel cells, each producing 1 V of electricity, connected in series for a nominal 28–31-V output. The sixth bay was left open and, on later Apollo missions, held advanced survey equipment for exploring the moon from orbit.

For all but the lunar landing itself, the CM housed the crew and crucial systems for life support, guidance and navigation, recovery, and control. These were wrapped in a complex heat shield for the astronauts' return through the earth's atmosphere. Anything not needed for reentry was placed in the SM, which was then discarded 12 minutes before the returning spacecraft hit the upper atmosphere.

The heat shield was a glass-phenolic honeycomb of more than 370 000 cells injected with a phenolic-filled epoxy; its thickness ranged from 0.75 inch at the top to 2.75 inches at one edge of the blunt base that would face into the line of flight during entry. The start-to-finish peak design heat load was 44 500 Btu/ft^2, although in fact no space capsule plunging through the earth's atmosphere ever was heated to the maximum of 37 522 Btu/ft^2 experienced by the unmanned Apollo 4's trial-by-fire qualification.

Several concerns led to NASA's decision to leave one man in lunar orbit on all the Apollo missions. Someone had to mind the Command/Service Module and, if necessary, to be prepared to maneuver it to a rendezvous with the Lunar Module if the LM became stranded in a lower orbit. Moreover, a three-man Lunar Module would have been too heavy and costly. In turn, each astronaut was given specific responsibilities in his assignment as commander, command module pilot, or lunar module pilot. The choice of who would actually land on the moon was set at the time of crew assignment (and reinforced by training), not by drawing straws shortly before embarking.

Thus, for 48 minutes during each 2-hour lunar orbit when the Columbia went behind the moon, command module pilot Michael Collins was the most isolated human in the universe. In his autobiography, *Carrying the Fire*, he noted that it was only when he saw the LM ascent stage growing in the distance as it approached Columbia for rendezvous that he allowed himself to think, "...we really *are* going to carry this thing off!"

July 21, 1969, 1:54:01 p.m., EDT (Mission elapsed time 124:22:01)

EAGLE: 'Forward 8, 7, 6, 5, abort stage, engine arm ascent, proceed. That was beautiful. 26, 36 feet per second up.'

The Eagle lifts off from the moon and ascends into a low lunar orbit for rendezvous with the Columbia 3 hours, 41 minutes later (5:35:00 p.m., EDT, mission elapsed time 128:03:00).

All throughout its development, the Apollo mission depended on a different kind of rendezvous: the art of bringing everything together. To do this, NASA first put the right people into key management positions. "Singling out individuals diminishes and takes from the very team nature of the undertaking," George Washington University's Logsdon said. "Together they were more than their sum as individuals."

Still, certain personalities made things happen. James Webb "was a perfect NASA administrator," Kelly said. "He knew how to hold off the external forces and let us do the engineering," Seamans said. "I used to tell him he was good at holding up an umbrella."

Webb, Seamans, and Mueller often worked as a closely linked troika to run NASA, knowing what decisions to make on their own and when to reach a consensus among themselves or with other managers at headquarters and the field centers.

"George Mueller was a guy who had the guts" to bring the "all-up" test decision to the head office and to bring in a number of senior Air Force managers, observed Seamans. Moreover, "it was hard to beat Sam Phillips," an Air Force general brought in to run Apollo. "He was really experienced at

managing big programs [including the Minuteman missile] with lots of contractors."

"Most people talk about tremendous organizational schemes," said Christopher Kraft, former Apollo flight operations director. "Bull. It worked because people did their jobs irrespective of what the organizational chart said. [Apollo spacecraft manager] George Low got it together in spite of the organization, not because of it."

The presence of teams with track records was essential, too: Huntsville's rocket team at Marshall Space Flight Center grew from the Army's ballistic missile team; what is now Houston's Johnson Space Center grew from Langley's pilotless aircraft work. They and all the contractors were not far removed from the discipline of developing and building systems in World War II.

NASA needed to track the many parallel elements and know when some minor part might become a roadblock on the "critical path" to the moon. The Program Evaluation and Review Technique (PERT) was adopted because the Navy had used it to produce the first Polaris submarine in less than three years. Despite its laborious punch-card accounting, the technique enabled NASA to orchestrate thousands of activities.

Still, a little connivance was sometimes needed. NASA wanted five of IBM's new 360/75 computers to capture and present all the data for flight directors in a single Apollo mission control center, but could not issue a sole-source contract. Leading computer companies were invited to submit bids with a firm price and delivery date. All the others needed time to develop a new machine. "IBM claimed it was a catalog item," Seamans said, and won the contract. "I think we bought the first ones."

Willingness to entertain new ideas was also a factor. Houbolt's arguments for Lunar Orbit Rendezvous eventually were accepted by von Braun, despite von Braun's early preference for Earth Orbit Rendezvous. "That showed me that von Braun was a fantastically big man," Houbolt said.

Total quality management and employee empowerment were practiced at Marshall long before the terms were invented. "Von Braun knew that the contractor and his engineers had to work together," Stuhlinger said. "He said, 'Let's work as a team and not push the responsibility off on one or another. We will enjoy the successes together.' This was one of the major reasons why this project was successful."

Another reason for success was also a seed of Apollo's demise: the goal was simple and victory was easily recognized.

July 24, 1969, 12:46 p.m., EDT

As the Command Module plunges into the earth's lower atmosphere, it makes first voice contact with the recovery ship, the aircraft carrier U.S.S. Hornet.

U.S.S. HORNET: *'Apollo 11, Apollo 11, this is* Hornet, *over.'*

APOLLO 11: *'Hello,* Hornet, *this is Apollo 11 reading you loud and clear.'*

Four minutes later, at 12:50:35 p.m., EDT (mission elapsed time 195:18:35), the Command Module splashes into the Pacific Ocean.

Six more trips to the moon were attempted; five made it to the lunar surface and one mission was aborted but the astronauts were saved by using the Lunar Module as a lifeboat. Interest waned as the pressures that created Apollo abated and were replaced by the demands of the Great Society and the war in Vietnam. Congress whittled the Apollo Applications Program until only Skylab space station (operated 1973–74) was left. Manned lunar exploration ended with the Apollo 17 mission in December 1972.

As the program wound down, NASA worried about the morale of people who soon would lose their jobs. Grumman president George Skurla responded pointedly, "Don't worry about my Grummies; they'll do O.K." The night before Apollo 17 left for the hills of Taurus-Littrow, "Grummies" taped a poster to the Saturn's LM access hatch. It was signed by all the team and read, "This may be our last LM, but it will be our best LM." The sentiment was common to all the teams.

A quarter century later, government and corporations have few tangible reminders of Apollo. Most of the German rocket team in Huntsville was laid off in the 1970s in what was regarded by some as an attempt to "Americanize" the space program. Draper Laboratories' last artifact, a training model of the guidance system control panel, sits in a corner of a simulator laboratory. Grumman was bought by Northrop, North American was swallowed by Rockwell Standard, and Douglas Aircraft was taken over by McDonnell.

Unused spacecraft went to museums. The last two Saturn V rockets are displayed lying on their sides, like beached whales, helpless and bereft of majesty. The Saturn V's manufacturing tools were sold for scrap and its plans were largely discarded as NASA Administrator Thomas O. Paine sacrificed Saturn to buy the reusable Space Shuttle. And the silver dollar that bears the Apollo 11 seal on its reverse carries the face of the president who did not want to fund Apollo.

Soon Johnson Space Center's extensive historical archives will be dispersed to Rice University in Houston and to a nameless Federal archive—a fate suggestive of the end the movie *Raiders of the Lost Ark,* where the Ark of the Covenant is crated up and hidden among myriad other anonymous crates in a Government warehouse.

Worst of all, since Apollo, NASA has seemed to lack direction. The office of John Gibbons, President Bill Clinton's science advisor, declined an interview request, citing no interest in the subject.

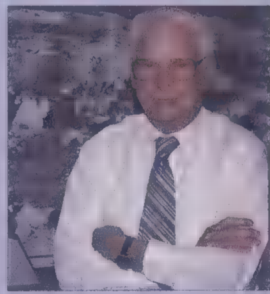
"The problem is that we have run out of moons," Stuhlinger recalled von Braun saying. Logsdon agreed that "we used up the one real good place to go real quick." Moreover, he pointed out, Apollo did not follow von Braun's scenario, outlined in 1952, for building transportation and operating services to support larger ventures in space.

Still, the Apollo program did achieve what it set out to do: land a man on the moon and return him safely to earth by 1970.

"In geopolitical terms, it was worth it," Logsdon said. "In many ways this large-scale effort was singularly warlike. It had a single, well-articulated goal by which you measured progress." As Kennedy had wanted, Apollo pitted the U.S. and Soviet systems against each other. "And," Logsdon added, "we operated the U.S. system at its best."

That was enough to answer the concerns of many U.S. citizens in the 1960s, such as the high school students Seamans recalled meeting aboard

For all mankind—and the public eye



Dave Dooling

Robert Seamans

Science fiction movies had for decades depicted the moon as having razor-sharp mountains and a flat spot to land on. Then the Lunar Orbiter probes showed the surface to be rolling and hummocky, offering a, well, boring landscape. So Robert Seamans, then NASA deputy administrator, asked the Lunar Orbiter team to tilt the spacecraft for a few pictures. The resulting striking view across Copernicus crater helped renew public belief that the moon would be an exciting place to visit.

Public interest in the lunar program was actively sought as vital to its success, Seamans noted. For that reason, the effort leading to the Apollo 11 launch and the moon landing was conducted in a fishbowl. "There was no question in the minds of NASA that we couldn't do it Manhattan-style," he said, referring to the secrecy surrounding the atomic bomb project during World War II.

The day after Alan Shepard's suborbital flight in May 1961, Secretary of Defense Robert S. McNamara noted that the public reaction in the United States was far better than the USSR received for Yuri Gagarin's orbital flight. "We accepted then that, like it or no, we had to do it in the open, and the payoff would be much greater," Seamans said.

Even through the intense scrutiny following the Apollo 1 fire, NASA was right about the long-term payoff. Seamans (who became secretary of the Air Force in 1967) watched the Apollo 11 launch with former President Lyndon B. Johnson. Then he went to Houston to join female-aviation pioneer Jackie Corcoran and others at Mission Control. Together, they watched the moon walk, as television looked over NASA's shoulders and brought the United States' triumph into the living rooms of the world.

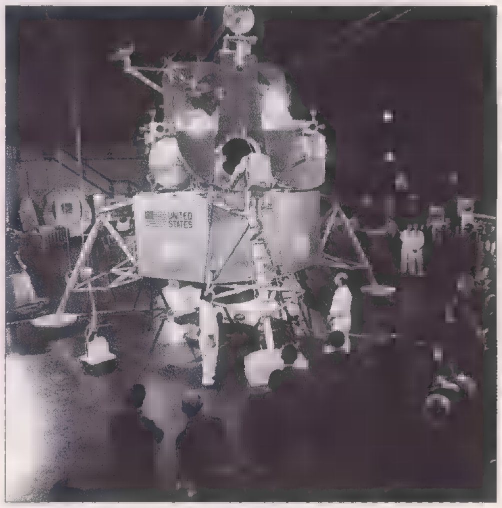
a U.S. Navy cruiser on a summer scholarship cruise before the landing on the moon. They asked him why their country was a second-rate space power, why the Soviets were winning the space race. "That kind of attitude can become self-defeating," Seamans said. "If we hadn't won [the space race], it wouldn't have been the end of the U.S. But we stood up to the challenge and I, for one, am glad we did."

Apollo's appeal to youth has not faded altogether. One day this March, Logsdon took several of his space policy students across the Potomac River to visit the control center for Clementine, the small lunar surveyor built by the Naval Research Laboratory. "This gray-haired guy sat down," he recalled, and was almost unnoticed until Logsdon introduced him as Dave Scott, commander of the Apollo 15 landing. "All of a sudden, an aura appeared around him" in the almost reverential way the students spoke to him. "Today's astronauts are a motley crew, but the Apollo astronauts are special. They're treated differently." Logsdon recalled another observer commenting, "No one gives parades for robots."

TO [redacted] FURTHER. Several commissioned NASA histories provide the official version of the race to the moon: *Chariots for Apollo* by Courtney Brooks, James M. Grimwood, and Loyd S. Swenson Jr. (NASA SP-4205, 1979); *Stages to Saturn* by Roger Bilstein (NASA SP-4206, 1980); and *Where No Man Has Gone Before* by William David Compton (NASA SP-4214, 1992).

Various authors discuss aspects of turning space flight from dream into reality in *Blueprint for Space,* edited by Frederick J. Ordway III and Randy Lieberman (Smithsonian Institution, Washington, D.C., 1992).

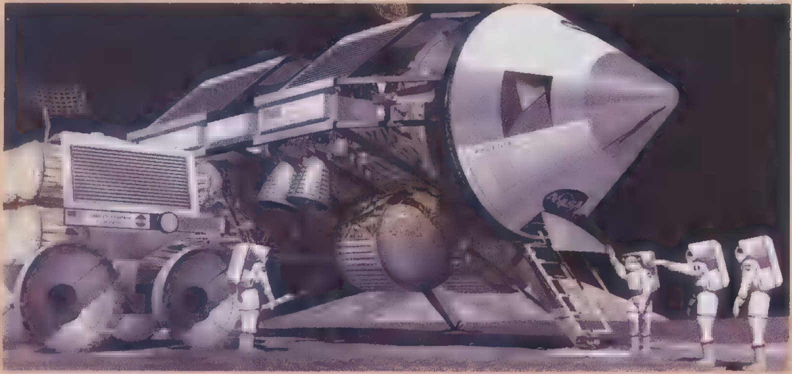
John Logsdon and Alain de Pas review the Soviet moon race in "Was the Race to the Moon Real?" in the June 1994 *Scientific American*, Vol. 270, no. 6, pp. 36–43. *Apollo Expeditions to the*



NASA/Grumman Aircraft Co.

A spacesuited test engineer demonstrated embarking and disembarking methods on a full-scale all-metal mockup of the Lunar Module. This fifth engineering mockup, designated M-5, incorporated most of Grumman Aircraft Co.'s final design concepts, and was representative of the actual flight model used on Apollo 11. The proceedings are watched by Grumman and NASA engineers and several astronauts during a late-1964 review.

Can we go back to the moon?



NASA

The Phoenix lander was designed in 1993 for a future return to the moon. The rover [left] would be used to replenish the lander's supply of liquid oxygen by cracking lunar oxides.

If we can put a man on the moon, why can't we…put a man on the moon?

"Most people ask, 'Why go?,' but I am trying to understand why we don't," said Wendell Mendell, former chief scientist for lunar base studies and now "resident realist" in the New Initiatives Office at Johnson Space Center in Houston, Texas. He watched Apollo 11 coverage at home with his family, but has a stronger memory of a Los Angeles radio station covering the Surveyor 1 landing on June 2, 1966, which confirmed that the lunar surface would not swallow man's first steps on another world.

"If we had the national will, could we go back?" Mendell asked. "A couple of elements are critical. One is the depth of resources you have when you have the national will. Apollo had almost unlimited resources, so when we got into trouble, we could get back out."

Returning would require proportionally deeper pockets. "The bureaucratic process we have developed costs money. So if you play by all the rules, you would spend proportionally more to generate a theoretical 'technology unit' than you did in the early '60s," Mendell asserted.

Further, NASA was not yet three years old when it started Apollo; now it is over 35. "A lot of people are process-oriented and not product-oriented," Mendell continued. "It happens in any large organization. It has become institutionalized in NASA and would be proportionally worse if we went back."

The second element is the willingness to take risks. "People are much more risk averse and [that] would require proportionally deeper pockets to cover every conceivable contingency," he said.

Following Apollo, plans for lunar missions faded until 1989, when President George Bush called for the United States to reach Mars by the year 2019. NASA responded with the first-cut 90-Day Study, then established the Space Exploration Initiative. The 90-Day Study resulted in a turnkey design with one large rocket carrying everything. That study influenced work leading to the First Lunar Outpost study, completed in February 1993, which suggested using two landers. One would deposit a habitat (derived from the space station), while the second would take a four-person crew in an Apollo-type module for a 45-day mission.

The landers would be launched by a derivative of the Saturn V, which space advocates want to resurrect. Yet, praise for the Saturn V usually ends with how "we can make it better if we use…" lithium-aluminum alloys and so on.

But in the current budgetary and political environment, new launch vehicles are not likely. So some elements in NASA are studying how to mine the lunar soil for oxygen, its most abundant element, locked in various metal oxides that can be cracked with another abundant resource: sunlight. Manufacturing the oxygen on the lunar surface to burn with the fuel for the return to the earth would reduce the spacecraft's launch weight.

With space station Freedom's problems, however, "things went downhill fast," Mendell said. As a result, "a significant missing element is trust between NASA and Congress....The whole relationship has been poisoned."

By late 1993, the Space Exploration Initiative was reduced to a small planetary team within the New Initiatives Office. Furthermore, NASA was criticized for not being as quick as the Department of Defense's Ballistic Missile Defense Organization (BMDO) when BMDO launched Clementine, the first U.S. post-Apollo foray to the moon. However, BMDO allows leeway and risk-taking, and Clementine sported sensors developed under separate projects.

Meanwhile, the European Space Agency held a lunar workshop last month in Switzerland. Invitees included the United States, Russia, and Japan. Japan's National Space Development Agency has the moon in its 45-year plan, and Shimizu Corp., Tokyo, plans a lunar hotel.

Mendell expects that history will repeat itself after a fashion. Some other nation will get back to the moon first, and a member of Congress will ask why everyone is doing it but the United States. So Mendell has assumed the same role as the Space Task Group in 1958, when its members started preserving technical options: "I want to have something in my pocket that is technically realizable and that can be done rapidly—and that requires no new launcher."

NASA

The tickertape parade for the Apollo 11 astronauts on Aug. 13, 1969, was the largest in New York City's history.

Appropriations for Project Apollo, in millions of U.S. dollars*

	Apollo spacecraft					
Fiscal year	Command/ Service Module	Lunar Module	Guidance, navigation, and control	Saturn [a]	Other costs [b]	Total
'62	52 [c]	[d]	[d]	—	108	160
'63	345	123	32	91	26	617
'64	546	135	91	1263	237	2273
'65	578	243	91	1434	269	2615
'66	615	311	115	1586	340	2967
'67	560	473	77	1422	385	2916
'68	455	400	113	1164	424	2556
'69	283	326	44	576	796	2025
'70	283	231	34	484	654	1686
'71	246 [c]	[d]	[d]	189	479	914
'72	55 [c]	[d]	[d]	142	404	601
'73	50 [c]	[d]	[d]	26	—	77
Total [c]	4068	2241	598	8377	4122	19 407

Source: *Where No Man Has Gone Before: A History of Apollo Lunar Exploration Missions* (NASA SP 4214), pp. 329–30.

*Current year dollars, not adjusted for inflation.
(a) Includes Saturn IB, Saturn V, and engine development.
(b) Includes integration, missions operations and support, and science.
(c) See (d).
(d) Included in costs of Command Service Module.
(e) Figures do not add exactly because of rounding.

Moon by Edgar M. Cortright (NASA SP-350, 1975) provides retrospective views on the fifth anniversary of the Apollo 11 landing.

For human perspectives, see: *Wernher von Braun, Crusader for Space* by Ernst Stuhlinger and Frederick I. Ordway III (Krieger, Malabar, Fla., 1994), about von Braun's life in rocketry; *Angle of Attack* by Mike Gray (Norton, New York, 1992), about program manager Harrison Storms, who was cashiered by North American after the Apollo 1 fire; *Chariots for Apollo* (a non-NASA history by the same title) by Charles R. Pellegrino and Joshua Stoff (Athenum Press, New York, 1985) about Grumman's work on the Lunar Module; and *Carrying the Fire* (Farrar, Straus & Giroux, New York, 1974), Michael Collins' autobiography.

10:56:20 PM 7/20/69 (CBS News, New York, 1970) is a screen-by-screen reprint of CBS's coverage of Apollo 11 from liftoff to splashdown.

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Higher visibility for LEDs

Hewlett-Packard Co.

The luminance and luminous efficiency of light-emitting diodes (LEDs) in the last few years have reached such high levels that they can replace incandescent lamps in running lights on trucks. Particularly where safety is involved, the longer life and inherent ruggedness of the solid-state devices make them ■ highly desirable substitute; the lower maintenance cost of the LEDs is a boon to any application.

More light—some of it blue—from less power unveils bright vistas of new applications for the latest light-emitting diodes

Ubiquitous, reliable, boring—those are the words many electronics engineers would use to describe light-emitting diodes (LEDs). Yet slow, steady advances in materials and structures now allow companies to produce red LEDs bright and efficient enough to replace incandescent lamps in automotive brake lights and traffic signals. Moreover, LEDs take about ■ million hours to degrade to half power, greatly reducing maintenance costs.

Even full-color outdoor video displays based on LEDs are now possible. A Japanese company with no track record whatever in semiconductor devices seems to have discovered the long-sought Holy Grail of LED technology—a blue LED with a luminous efficiency high enough to make it adequately bright at reasonable power levels.

Back in 1962, when the technology was first commercialized by General Electric Co., the visible-light LED was arguably the simplest solid-state light-producing electro-optical device imaginable [Fig. 1]. It consisted of a forward-biased p-n junction fabricated in ■ III-V compound—a semiconducting material composed of chemical elements from columns III and V of the periodic table. When the bias voltage reached the level associated with the material's energy gap (E_g), injection of minority carriers—electrons into the p material and holes into the n material—became appreciable, and significant conduction occurred. The minority carriers combined with majority carriers, liberating photons with an energy approximately equal to E_g.

Ken Werner Contributing Editor

The earliest material for visible-wavelength LEDs was gallium arsenide phosphide (GaAsP), with an energy gap that could be as large as 2.03 electron volts for an appropriately chosen ratio of As to P. The wavelength of the emitted radiation, l, equals the product of Planck's constant, h, and the speed of light in ■ vacuum, c, divided by E_g; so for an E_g of 2.03 eV, the wavelength was 610.5 nm—which is red.

The early LEDs had a luminous efficiency of less than 0.2 lumen per watt. There were two reasons for the poor luminous performance of these early LEDs: low internal quantum efficiency and low extraction efficiency. Indeed, the history of LED development to date has centered on the Herculean effort to improve the device's quantum and extraction efficiencies.

A LITTLE DEVICE PHYSICS. An LED's internal quantum efficiency is simply the number of photons generated divided by the number of minority carriers injected. In an LED, most of the minority carriers are electrons injected into the p-doped region, so that the mental picture can be simplified to one of electron injection alone.

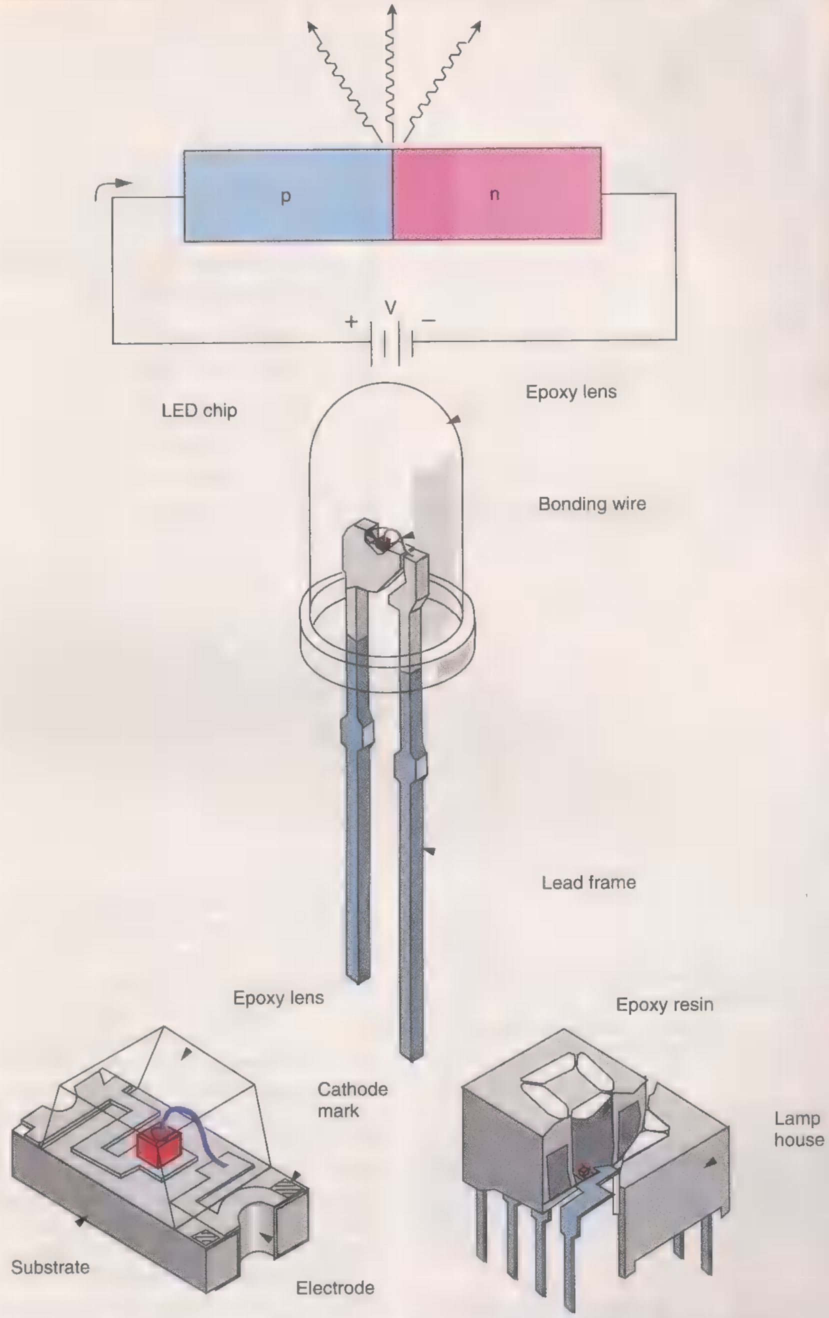
Stanley Inc.

The electronic outdoor signs that festoon the urban landscape in Asia constitute a high-volume application for LEDs.

Combining an injected electron with a hole to produce a photon is called, logically enough, ■ radiative recombination. If all the injected electrons recombined and all the recombinations were radiative, the internal quantum efficiency would be 100 percent. Device designers can make nearly all injected electrons recombine without much difficulty, but ensuring a high proportion of *radiative* recombinations is another story.

If an injected electron remains free in the p-region long enough, it will encounter a hole and recombine radiatively. But other kinds of transitions compete with radiative recombination for each injected electron. The important common characteristic of these other transitions is their failure to produce photons—that is, they are nonradiative recombinations [Fig. 2]. These transitions occur at crystal imperfections of various sorts and dissipate their energy into the crystal lattice as heat.

Characteristic lifetimes of injected elec-



Source: (top) *Flat-panel Displays and CRTs*, L.E. Tannas Jr., ed., Van Nostrand Reinhold, 1985; (center and bottom) LED catalog, I.I. Stanley Inc.

[1] A basic visible-light–emitting diode is a simple electro-optical device. It utilizes a forward-biased p-n junction [top] in a semiconductor material that has a band gap capable of producing photons with visible wavelengths. Devices are in many forms, including [anticlockwise from center] lamp-type, chip-type, and numerical-display structures.

Defining terms

Brightness: a subjective attribute of light. It is described as varying over a range from very dim to blinding and is often used, erroneously, in place of luminance [see below], an objectively measurable quantity. With all other conditions constant, increasing the luminance will increase the sensation of brightness, but the relationship between luminance and brightness is highly nonlinear.

Light: radiant energy able to stimulate the retina and initiate a visual sensation. (Note that this definition excludes ultraviolet and infrared wavelengths, whereas physicists—including those working with LEDs—tend to call them all light.)

Luminance: the luminous intensity per unit area projected in a given direction. The SI unit is the candela per square meter, sometimes called a nit. The foot-lambert, while deprecated by metric purists, is still in common use. (1 fL equals 3.426 cd/m^2.)

Luminous efficiency: the ratio, measured in lumens per watt, of luminous flux (see below) to the electric power that produced it. Since a true efficiency can only be expressed as a percentage, this use of the word "efficiency" is not formally correct. Therefore, in the information-display and illumination engineering worlds, "luminous efficacy" is sometimes used. The equivalent term in the LED literature is "luminous performance."

Luminous flux: "visible power" measured in lumens. At a wavelength of 555 nm—the yellow-green light to which the human eye is most sensitive—1 W of radiant power is equivalent to a luminous flux of 680 lm. The eye's sensitivity falls off sharply; at 510 and 610 nm, 1 W is equivalent to only 340 lm.

Luminous intensity: the luminous flux per solid angle emitted from a point, measured in lumens per steradian, or candelas (cd).

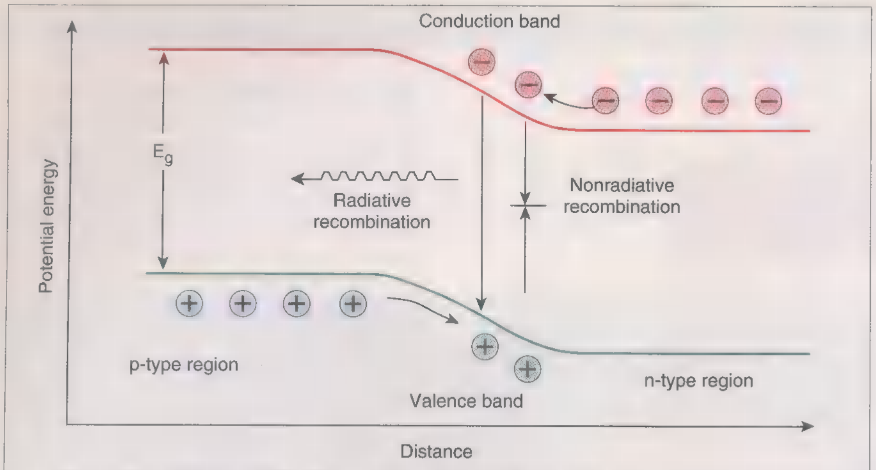
trons before they encounter ■ radiative recombination (τ_r) or a nonradiative one (τ_{nr}) can be determined for any semiconducting material. If τ_r is much less than τ_{nr}, the internal quantum efficiency will be very close to 100 percent, as in gallium arsenide (GaAs) devices. (For them, a typical τ_r is 5 x 10^{-9} second.) Unfortunately for visible-light applications, GaAs emits in the infrared part of the spectrum, and most other semiconductors have a much lower internal quantum efficiency.

The external—or overall—quantum efficiency of any LED is often much lower than its internal quantum efficiency because many photons never leave the device. Finding ways of improving the extraction efficiency—the percentage of generated photons that actually find their way out of the device—has contributed as much to overall performance as have the more exotic efforts to improve internal quantum efficiency. Discussion of these approaches can wait till later. For now, a return to the semiconductor energy gap and the wavelength of light produced by an LED is in order.

The energy gap of a semiconductor is the minimum energy separating the valence band and the conduction band. Each band contains the possible combinations of energy and momentum for one type of carrier—the valence band those for the carriers of positive charge (holes) and the conduction band those for the negative charge carriers (electrons).

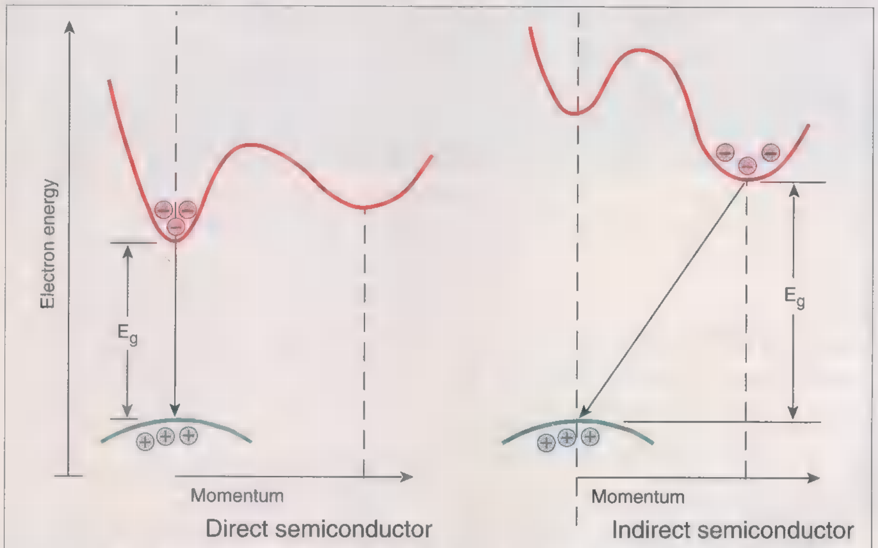
The simplest situation occurs when E_g is found at the point where the hole and electron momenta are both zero [Fig. 3, left]. An electron and hole can then readily combine and in so doing emit ■ photon, because the interaction conserves energy and momentum. Energy is conserved because the energy of the emitted photon equals the energy lost by the electron as it combines with the hole. Momentum is conserved because the electron and hole momenta were both essentially zero to begin with, and photons have almost no momentum.

This kind of gap is called ■ direct energy gap, and the semiconductor that contains it is called a direct semiconductor. Clearly, direct semiconductors favor radiative recom-



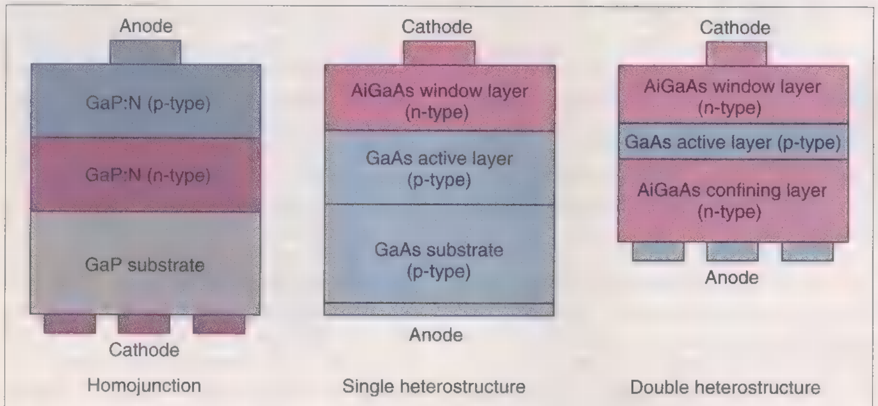
Source: *Flat-panel Displays and CRTs*, L.E. Tannas Jr., ed., Van Nostrand Reinhold, 1985

[2] In an LED, electrons injected across the p-n junction combine with holes in radiative recombinations, which produce photons, or in nonradiative recombinations, which do not.



Source: *Flat-panel Displays and CRTs*, L.E. Tannas Jr., ed., Van Nostrand Reinhold, 1985

[3] Electrons in the conduction band of a direct semiconductor have essentially zero momentum and can directly recombine with a hole, producing a photon. In an indirect semiconductor, a more complicated interaction is required to conserve momentum.



Source: "Light-emitting diodes," M. George Craford and Frank M. Steranka, *Encyclopedia of Applied Physics*, Vol. 8, VCH Publishers, 1994.

[4] The simplest LEDs [left] are formed by epitaxially growing an n-type film on a substrate and creating a p-type junction in the film. They are called homojunction devices because both sides of the junction are formed from the same basic material. A single heterostructure [center] overcomes some of the limitations of homojunction devices by using a different material for the p and n sides of the p-n junction. In a double heterostructure [right], an additional layer of material confines injected electrons within the active layer.

bination. Unfortunately, the only colors available from early direct semiconductors suitable for visible LEDs were shades of red.

A wider range of colors was available from another class of devices, indirect semiconductors, in which the holes still cluster around zero momentum but the electrons cluster around a nonzero momentum [Fig. 3, right]. Thus a recombination that emitted only a photon of energy E_g would conserve energy but not momentum, and therefore cannot occur.

The only way a radiative recombination can take place in these circumstances is for the interaction to produce a particle (or something capable of acting like a particle) that can carry away the initial electron momentum. Fortunately, an appropriate something exists: a quantum of vibrational energy in the crystal lattice—a phonon—that produces heat transfer to (or from) the lattice. Thus the interaction of concern is one in which an electron in the conduction band combines with a hole in the valence band, simultaneously producing a phonon and a photon. The combined energy of the resultant phonon-photon pair equals E_g and the sum of the initial electron momentum and the phonon momentum equals zero.

One of the principles of particle physics is that, if an interaction can happen, it will. But the combination of conditions that allows an indirect radiative recombination to occur is far less likely than the simpler set of conditions that permits a direct radiative recombination. As a result, indirect semiconductors are characterized by a longer recombination time (τ_r) and a larger ratio of recombination to nonrecombination (τ_r/τ_{nr}) than are direct semiconductors, as well as relatively low quantum efficiencies.

DIRTY TRICKS. Many commercial devices are made from such indirect semiconductors as gallium phosphide (GaP), which produces green, and silicon carbide (SiC), which produces blue. From the beginning, there was intense interest in improving the luminous performance of these devices.

One approach is to add an isoelectronic impurity—one from the same column of the periodic table as the element it replaces. An example is nitrogen in GaP, designated GaP:N. Each nitrogen atom creates a localized strain in the crystal that can trap an electron. The electrons are bound so firmly that there is little uncertainty as to their position. But there is, according to the Heisenberg uncertainty principle, a large statistical uncertainty in their momentum. The uncertainty is large enough for each electron to have a significant probability of having zero momentum and undergoing a direct radiative recombination. This quantum-mechanical trick raises the radiative recombination rate, but not enough to rival the rate in direct semiconductors.

Another trick is to use such three-element alloys as $GaAs_{1-x}P_x$ and such four-element alloys as $(Al_xGa_{1-x})_{0.5}In_{0.5}P$. The energy gap can be varied by altering the propor-

tions of the elements in the alloy, and many of these semiconducting alloy systems change from an indirect to a direct semiconductor at some composition—some value of x in the chemical expressions above—that dramatically increases the quantum efficiency. When GaAsP contains 70 percent GaP, for instance, its quantum efficiency is about 2×10^{-5}. When it contains 25 percent GaP, its quantum efficiency is 8×10^{-3}.

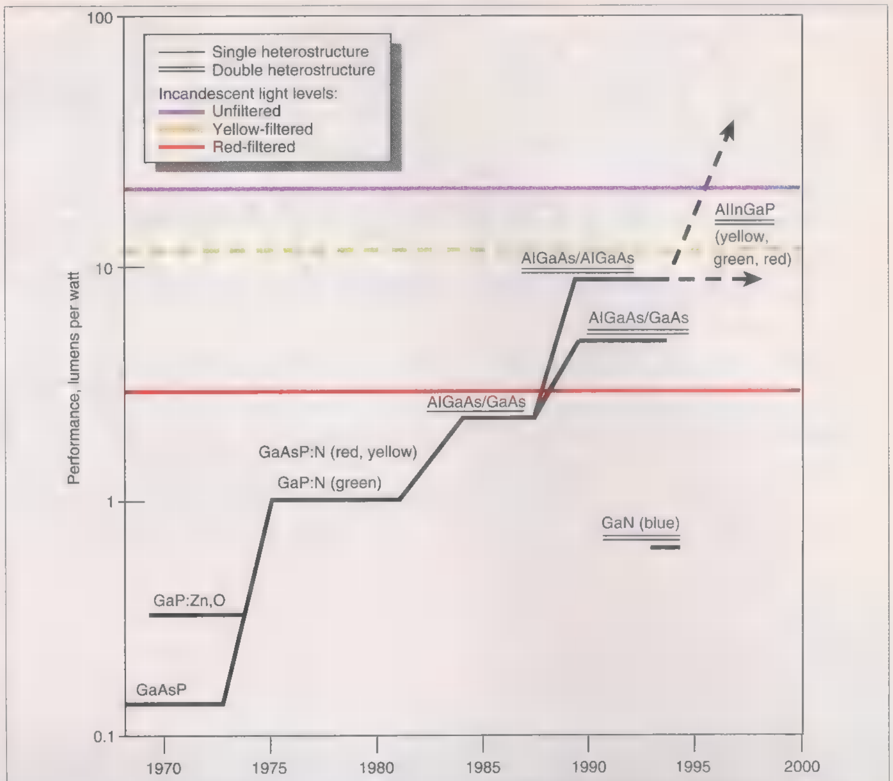
FABRICATING LEDs. To what extent have these materials developments allowed LED designers to develop highly efficient devices in different colors? Consider the structure of a GaP:N diode [Fig. 4, left]. The n-type film is epitaxially grown on the substrate, and the junction is formed by diffusing a p-type dopant into the film or by changing the dopant during the growth of the epitaxial film. In either case, both sides of the junction are formed from the same basic material, so devices of this kind are called homojunction devices.

These devices can be made easily and economically, but they have severe limitations. To maximize quantum efficiency, designers would like to dope both sides of the junction heavily. However, this produces a deep junction—one quite far below the anode contact in Fig. 4. As a result, in direct semiconductors, many photons are absorbed by the semiconducting material before reaching the anode surface where they are emitted. But if the junction were shallow (which would also result in a lightly doped layer that would not produce or convert injected electrons efficiently), a lot of the injected electrons would reach the surface before they could recombine and produce photons. (Surface recombination is usually nonradiative.)

In indirect semiconductors, photons are absorbed much less readily, so junctions can be deep. However, heavily doping the n-type side of the junction (as is needed for effective electron injection) inevitably shortens the nonradiative lifetime. The standard compromise is suboptimal doping and reduced device efficiency.

Many of the tradeoffs inherent in homojunctions can be resolved by using different materials for the two sides of the p-n junction—which is called a single heterostructure or single heterojunction [Fig. 4, center]. The device is fabricated by growing a window layer of n-type AlGaAs on the active layer of p-type GaAs. The window layer is transparent to the photons generated in the active layer, and can therefore be made thick enough to minimize surface recombination. Even though the n-type window layer is lightly doped, its proximity to the GaAs p-type layer, with its smaller band gap, produces efficient electron injection.

STRUCTURAL ADVANCE. This structure was a distinct advance in LED technology. Devices based on it typically have an external quantum efficiency of 4 percent and a luminous performance of 2 lumens per watt. But problems remain. Some of the injected electrons penetrate deeply into the active region before recombin-



Source: "LEDs Challenge the Incandescents," M. George Craford, *IEEE Circuits & Devices Magazine*, September 1992.

[5] The luminous performance of LEDs has risen by a factor of 100 over the last 25 years, and more improvements are in sight. A milestone was passed when the performance of red LEDs exceeded that of red-filtered incandescent lamps, opening the automotive brake-light market to solid-state devices. Full-color displays require red, blue, and green, but until very recently no blue diodes performed well enough even in a laboratory.

Some visible-light-emitting diodes characterized

Structure	Material	Bandgap type	Peak wavelength, nm (color)	Typical performance, lm/W
Homojunction	GaAsP	Direct	650 (red)	0.15
	GaP: Zn,O	Indirect	700 (red)	0.4
	GaAsP: N	"	630 (red), 585 (yellow)	1
	GaP: N	"	565 (yellow-green)	2.6
	GaP	"	555 (green)	0.6
	SiC	"	480 (blue)	0.04
Single heterojunction	AlGaAs	Direct	650 (red)	2
Double heterojunction	AlGaAs	Direct	650 (red)	4
	AlGaP	"	620 (orange)	20 [a]
	AlInGaP	"	595 (amber)	20 [a]
	AlInGaP	"	570 (yellow-green)	6 [a]
	GaN	"	450 (blue)	0.6
Double heterojunction with transparent substrate	AlGaAs	Direct	650 (red)	8

Source: based on "LEDs Challenge the Incandescents," M.George Craford, *IEEE Circuits & Devices Magazine*, September 1992

(a) Best reported results; typical commercial performance not established.

ing, and many of the photons produced by these interactions are absorbed before making their way to the surface. Of course, photons emitted downward will be absorbed.

To utilize these wasted photons, designers developed a double heterostructure. An active layer is sandwiched between two layers fabricated from materials (or a material) different from that of the active layer with larger energy gaps [Fig. 4, right]. The upper layer is still called the window layer; the lower layer is the confining layer, whose larger energy gap keeps the injected electrons from penetrating beyond the heterojunction. This allows designers to make the active region thin, which minimizes absorption.

GETTING THE LIGHT OUT. The external quantum efficiency of an LED equals its internal quantum efficiency multiplied by the device's extraction efficiency. Extraction efficiency is usually much less than 1; extracting light from an LED semiconductor chip is difficult. Because of absorption losses, reflection at the junctions, and total internal reflection at emission angles greater than the critical angle—about 25 degrees for epoxy-encapsulated diodes—the extraction efficiency can be as low as 4 percent if the active layer is thin and emission through its edges is therefore negligible. As a result, even a superb LED material with an internal quantum efficiency of 100 percent will end up as a device having an external efficiency of only 4 percent!

Designers at companies such as Hewlett-Packard Co. in the United States and Toshiba Corp. and Stanley Electric Co. in Japan did not labor long and hard on problems of quantum mechanics and device structure to be defeated by problems in classical optics. They proceeded to make the active layer quite thick—up to tens of micrometers—which produced good edge emission and raised the extraction efficiency to more than 10 percent.

In double heterostructures, it is possible to grow a confining layer so thick—greater than 100 μm—that the substrate can be completely removed. The confining layer then serves as a new, transparent substrate. In a device with a transparent substrate, a great deal of the light that is emitted downward reflects from the back of the chip and escapes. As a result, the extraction efficiency can rise to about 30 percent.

Commercial red LEDs made of AlGaAs with a double heterostructure and transparent substrate currently produce in the vicinity of 10 lm/W. So do red, orange, and yellow LEDs made of AlInGaP with an absorbing substrate. Transparent-substrate AlInGaP devices about to enter commercial manufacturing are producing 20 lm/W.

Fred Kish and his colleagues at Hewlett-Packard have recently reported an orange, 40-lm/W device. This is one of a new family of transparent-substrate devices fabricated with semiconductor wafer bonding. The original n-type absorbing GaAs substrate on which the subsequent device layers have been grown is chemically etched away. The remaining layers are then wafer-bonded under heat and pressure to a transparent n-type GaP substrate about 0.25 mm thick.

The 40-lm/W device from this family has a luminous performance that is better than that of an unfiltered halogen bulb. Across the entire visible spectrum, the new architecture produces devices with double the luminous performance of the best previous devices, according to Kish.

MILESTONES AND USES. When the first visible GaAsP LEDs were commercialized in 1962, they would have made Henry Ford feel pretty much at home: customers could have any color they wanted, as long as it was red. The luminous efficiency of these devices was 0.15 lm/W [Fig. 5], suitable for many indicator lamps and numerical readouts but nowhere near outshining the 3.5 lm/W of a red-filtered incandescent lamp.

With the development of isoelectronically doped indirect semiconductors in the mid-1970s, diodes became both brighter and more varied. Red and yellow diodes made with GaAsP:N and green diodes made with GaP:N were producing about 1 lm/W. Single-heterostructure AlGaAs/GaAs diodes raised the state of the art to 2 lm/W.

By about 1989, double-heterostructure AlGaAs/GaAs and AlGaAs/AlGaAs diodes exceeded the luminous efficiency of red-filtered incandescent lamps, opening up a lucrative market: the replacement of automotive brake lights [Fig. 6]. Several automobile models now use such LEDs in the braking lights mounted in the center of their rear windows—the so-called center high-mounted stop lights, or CHMSLs. Running lights for the sides of both cars and trucks are other possible applications.

Interior and exterior displays commonly use red AlGaAs, green GaP:N, and red, orange, and yellow GaAsP/GaP or GaAsP:N LEDs [Fig. 7]. The recently developed AlInGaP material system is already producing devices that are superior to all others in luminous efficiency between 590 nm (yellow) and 620 nm (orange). George Craford of Hewlett-Packard Optoelectronics predicts it will soon be the material of choice from 550 to 630 nm. Clarence Bruce, director of marketing for AND, Burlingame, Calif., says that AlInGaP will be the workhorse material for the next few years.


Hewlett-Packard Co.

[6] The center high-mounted stop light seen in the latest cars is one of the high-volume applications opening to state-of-the-art LEDs that outperform red-filtered incandescents.


Trans-Lux Corp.

[7] Gaming displays built around LEDs create an impressive, informative, and reliable environment for horse players at the Mirage Casino-Hotel in Las Vegas, Nev.

RISC SERVERS OPTIMIZED FOR WINDOWS NT

The Windows NT™ environment is opening a new era of multitasking, client/server computing. NEC has developed a pair of RISC-based systems that maximize the capabilities of Windows NT.

The NEC Express RISCserver™ is built around our 64-bit VR4400MC™ MIPS® RISC microprocessor, operating at 150MHz internally.

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NEC Express RISCservers and Image RISCstations are on sale in North America.

VSAT FOR VAST-AREA NETWORKING

One of the most efficient ways to establish a nationwide or worldwide network is to use a VSAT (Very Small-Aperture Terminal) satellite communications system. VSAT systems are reliable and economical for corporate networks or public infrastructures. They provide optimum solutions for data, voice, image and video communications.

NEC is an industry leader in supplying and implementing VSAT networks around the world. Our 4th-generation NEXTAR™-IV System provides efficient satellite access based on our proprietary Advanced Adaptive Assignment TDMA* scheme. It handles interactive and batch data transmission, as well as stream data, LAN data and voice/fax communications. Data broadcasting/video reception are add-on options.

Recent orders for our VSAT systems have come from a securities company in China, leading banks in Mexico and a steel-industry group in Russia, as well as from service providers in Argentina, China and Russia.

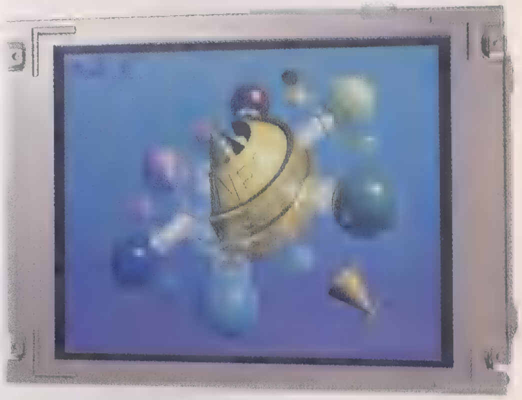
* Time-Division, Multiple-Access

FULL-COLOR TFT LCDs FOR MULTIMEDIA

NEC is introducing a 24cm (9.4-inch) LCD designed for TV/PCs and multimedia applications. The new TFT (thin-film-transistor) active-matrix LCD displays moving pictures in natural color.

The screen uses an analog RGB interface to display NTSC TV pictures or computer graphics of 640 x 480/400 pixels. It combines full-color capability with low power consumption of only 11W. The LCD module measures 257mm wide, 179mm high and 16mm deep. It weighs 800g.

The analog interface consists of three chips: analog interface, data inverter and analog driver. To achieve low power consumption and high speed, NEC used CMOS and BiCMOS technologies in the chip set. NEC plans to develop a 17cm (6.5-inch) full-color LCD using the same analog input technology.



HIGH-PERFORMANCE ATM CHIP SET

NEC now offers an advanced two-chip ATM (Asynchronous Transfer Mode) solution for the emerging multimedia LAN and WAN markets. Our chip set is ideal for use in ATM network interface cards for servers, workstations, internetworking equipment and digital video sets.

NEC's local ATM SAR chip handles all processing for the ATM layer and Segmentation and Reassembly in the ATM Adaptation Layer (AAL). Our chip fully supports the AAL5 and assists the AAL1 and AAL3/4 for voice, video and data transmission.

Our local ATM SONET framer supports the Transmission Convergence sub-layer and SONET in the physical layer. It performs high-speed data transmission with a 156Mbps (SONET STS-3c) serial interface and 19.44MHz parallel interface.

NEC's chip set also features wide 32K virtual connection support, UTOPIA-based interface and generic DMA controller for easy connection with popular buses such as SBus and PCI. The chip set conforms to ITU-TS, ANSI T1S1 and ATM Forum recommendations.

What's been missing is the color blue, with which manufacturers could make white LED lamps and full-color LED displays, including full-color outdoor and stadium displays. Eye-catching electronic billboards—relatively uncommon at present in North America and Europe (except in places like Times Square and Las Vegas)—are a standard feature of Asia's urban landscapes. The market for a bright, reasonably priced blue diode in such applications is huge.

Blue diodes made from silicon carbide (SiC), with an indirect band gap of 2.86 eV, do exist. However, they suffer from a very low luminous efficiency of about 0.04 lm/W so research has focused on finding an isoelectronic dopant for SiC to boost its efficiency.

TRUE BLUE. But recently, almost out of the blue, a chemical company with no background in manufacturing semiconductor devices announced a double-heterostructure blue LED [Fig. 8] made from zinc-doped indium gallium nitride (InGaN) and aluminum gallium nitride (AlGaN). The company, Nichia Chemical Industries Inc., Anan, Tokushima, Japan, is the country's largest producer of fluorescent materials, including those for fluorescent lamps. It brought its GaN diode to market two years earlier than the most optimistic estimates of industry leaders. According to Tomoji Ogawa of Nichia America Corp., the company's success hinged on solving two long-term problems in the fabrication of GaN devices.

The first problem was that GaN usually comes out as n-type when grown, and producing high-quality p-type material has proved extremely difficult. But in 1991, Shuji Makamura, a principal scientist at Nichia, disclosed a technique for forming p-n junctions in GaN by converting magnesium-doped GaN to p-type using N_2 ambient thermal annealing. The current zinc-doped InGaN devices uses a variation on this technique.

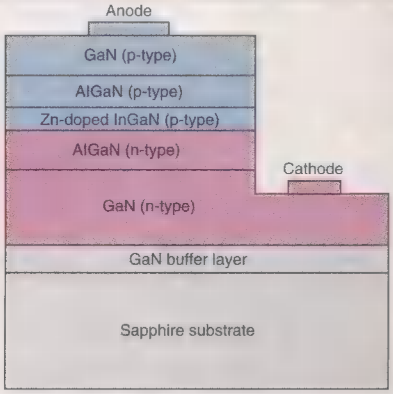
The second problem was that no substrate has a crystal lattice well-matched to GaN; the closest is sapphire (Al_2O_3), but the match is so poor that epitaxial GaN films grown on the sapphire have a high defect density. Progress came with the idea of using polycrystalline aluminum nitride (AlN) as a buffer layer between the sapphire and GaN to cushion lattice mismatch. Then, Nichia's Nakamura substituted polycrystalline GaN for the AlN and performance improved dramatically.

Nichia's commercial diode has an external quantum efficiency exceeding 2 percent, as compared to SiC's 0.02 percent. The units typically produce a luminous intensity of 1000 millicandelas, about 100 times greater than that of existing devices. (It is a peculiarity of the industry that luminous intensity is often specified in millicandelas even when the numbers involved are 1000 or more.) Widely available red and yellow LEDs produce 2000 mcd, and the bright orange, double-heterostructure AlInGaP LED recently introduced by AND produces 18 000 mcd.

Nichia started manufacturing its blue diodes at a rate of 1 million per month in


Nichia Chemical Industries Ltd.

[8] Blue gallium-nitride LEDs from Nichia Chemical Industries Ltd. outshine earlier silicon carbide diodes. The total luminous flux of each device shown above is actually the same; the apparent difference in brightness is due to the uneven angular distribution of their luminous intensity. The double heterostructure [below] of the devices is complex but overcomes difficulties in doping and in matching crystal lattices.



Source: Nichia America Corp.

April and sells them for US $5 each in quantity. In comparison, the bright AND unit costs $5.73 each in quantities of 500, and Stanley's 3000-mcd red diode costs $2.00 to $2.50 in quantity. One industry marketing executive said that to sell in very large numbers, the prices must fall to less than $1.

AND's Clarence Bruce predicts that the price of today's brightest AlInGaP LEDs will fall to about 25 cents within the next five years. At that level, many small light bulbs in industrial applications should be replaced by LEDs, he said.

A potentially lucrative market is the replacement of incandescent light bulbs in traffic signals. The long-lived bulbs they now use are not expensive, but failures are potentially dangerous, replacement disrupts traffic, and the labor and equipment required to replace a bulb are expensive. The essentially unlimited lifetime of LEDs—degradation to half brightness has been estimated at 1 million hours—is therefore very attractive.

LEDs are packaged as traditional lamps, as chips that are automatically mountable from tape, and as modules for numerical displays, as well as being made into waterproof lamp modules. In another standard configuration, an LED and a photoreceptor are mounted in the opposite prongs of a two-armed plastic housing. The resulting unit serves to detect the presence of a floppy disk when it is installed in a disk drive or the presence of paper in a laser printer.

Rectangular LED light bars put two or more LED chips in an epoxy package and are used for backlighting stenciled messages. Long, thin, flexible packages containing dozens of LED chips are used as backlights for small liquid-crystal displays. Stanley is about to introduce a compact right-angle surface-mount LED package, which has not been available until now. As a result, Stanley's customer, Dialight, has had to mount a prism on top of a Stanley surface-mount LED. Stanley applications engineer Don Clary is enthusiastic about the possibilities.

PLAYERS AND PROSPECTS. The top tier of LED manufacturers comprises Hewlett-Packard, Matsushita, Sharp, Stanley, and Toshiba (in alphabetical order). Among the other manufacturers, AND is producing state-of-the-art products, and Nichia seems to have the only bright blue diodes.

Many vendors offer packaged LED displays and instruments for specialized applications. For one, Trans-Lux—the developer of the first large-scale moving display in 1923—makes a variety of displays for financial and gaming applications. Also, Teledyne produces its own LEDs and assembles them into instrument readouts, light bars, and indicators for avionics applications.

As pervasive as LEDs may seem today, they will likely become far more common. The rapidly improving luminous efficiency of LEDs will let them compete with incandescent bulbs in applications where reliability, rather than power consumption, is the key issue. Moreover, the new generation of devices will be far less demanding on the power budget of battery-operated systems than were older LEDs.

Development of the bright blue LED may open the way for white LED light sources that could be used as, for example, backlights for laptop computer screens. When—and perhaps before—the blue diodes drop in price, they will almost certainly lead to large full-color video screens, which manufacturers may well field as direct competitors of such CRT-based stadium displays as the Sony Jumbotron.

TO PROBE FURTHER. A clear and detailed review of the physics, fabrication, and evolution of light-emitting diodes can be found in "Light-Emitting Diodes," by M. George Craford and Frank M. Steranka, a chapter in the *Encyclopedia of Applied Physics*, Vol. 8 (VCH Publishers, 1994, ISBN 1-56081-067-X). Less demanding slices of this material appear in Craford's "LEDs Challenge the Incandescents," *IEEE Circuits & Devices Magazine*, Vol. 8 (September 1992), pp. 24–29, and "LEDs Get Brighter...Much Brighter" in *Information Display* magazine, Vol. 9 (February 1993), pp. 12-14. The most recent textbook on LEDs is *Light Emitting Diodes—An Introduction* by Klaus Gillessen and Werner Schairer (Prentice-Hall, 1987). ◆

A Capitol experience

An engineer recollects the year he spent as an IEEE Congressional Fellow, serving as a legislative assistant to a U. S. senator

"They play hardball here, George." Orin Marvel pushed his chair back from the table in the Senate cafeteria, took another sip of his coffee and continued to discuss the differences between working as an engineer and as a congressional staffer. He and Glenn Heidebreder, who were completing their terms as IEEE Congressional Science Fellows, talked about the value of having as many interviews as possible, pointing out that they would help me build a network of Capitol Hill contacts—a staffer's lifeline. They gave me advice on how to get past the gate keepers and see the people who make decisions about staffing. They talked about the duties of a staffer and how to be an effective one. When lunch was over, they wouldn't even let me pay for their sandwiches.

I had applied for an IEEE Congressional Fellowship mostly from personal curiosity about how government really works. News of my appointment had arrived less than two weeks before this meeting. I figured that Orin and Glenn, who had been in my position just a year earlier, should be able to give me good advice. But as I thanked them and went back to my car, the things they told me kept tumbling in my head like colored bits in a kaleidoscope.

That was 10 years ago, and a kaleidoscope is still the best metaphor I can find for the experience of working on the personal staff of a U.S. senator. It was a year of jumping from one topic to another, of hurried meetings, of learning half a dozen new skills, of going home every evening to see the evening news announcers discuss what had been the office gossip of the day. It was a strenuous year, but it taught me skills I have found useful ever since [see "When the Fellowship year ends," p. 43] and made me understand how nearly ungovernable the United States really is.

George F. Swetnam Jr. The Mitre Corp.

"The framers of the Constitution did not give us a government of statesmen, but of representatives." Mark Talisman had spent many years as an administrative assistant to Representative Charles Vanik (D–Ohio), and he was one of the first speakers in the orientation session run by the American Association for the Advancement of Science (AAAS) for some 33 Fellows from a dozen or so academic and engineering societies. He went on to observe that members of Congress, although not all wise, good, or honest, are nonetheless a representative group of Americans—some brilliant, some decently plodding, some self-serving. "The quality of the member you work for is going to count more than whether he or she is a veteran or freshman, or sits on the majority or minority side of the aisle."

Getting a post with a member of Congress turned out to be a grinding series of cold calls on the offices that earlier fellows, independent research, and a few hunches suggested as likely spots. The picture that emerged was a collage of 535 special situations: all members of Congress have their own styles, priorities, and organizations. Some staff members were surprisingly frank about what they would expect me to do: push a particular measure or do something else for the member's district. Some offices, having employed Congressional Fellows before, had dotted-line boxes in their organizational charts labeled, "Put Congressional Fellow Here." Others had no idea what a Congressional Fellow was and wondered if they should refer me to the Library of Congress or the National Zoo. But my salary wouldn't come out of their budgets, and that helped me.

IN PLACE. In the end, I secured a spot on the personal (as opposed to committee) staff of Senator Bill Bradley (D-N.J.). In addition to respecting the man himself, I liked the way he organized his operation. Most of the other 20-odd offices where I had interviews appeared to operate on the edge of chaos. Bradley, who is sharp and conscientious, put me through a job interview that was one of the most intense grillings I have ever had.

Peter Wallace

Whatever subject you may have written about in your dissertation, on the Hill every staffer is a generalist. As a legislative assistant (LA), I was assigned two subject areas, transportation and the environment, chiefly for the convenience of the receptionist and the clerks in the mail room, so they would know where to direct constituents, lobbyists, and mail. The Clean Water Act, my chief responsibility, was up for renewal in the 98th Congress. In the end, the 98th Congress closed without passing the revisions, but we spent a lot of time in preparation and negotiation with other Senate offices.

I had to bone up on such topics as the economics of the proposed sale of Conrail, a government-owned network of railroads; whether RoadRailer trailers (large trailers with steel wheels they can lower to permit them to roll on railroad tracks) should be taxed at the same rate as

piggyback trailers (conventional truck trailers strapped onto railroad flatcars); whether a desolate, abandoned Army post had become a wildlife refuge through neglect; how the way benzene rings are joined affects the toxicity of the resulting compound; why it was important that a piece of dry land could be legally classified as navigable water; and what kinds of fish are the most likely to accumulate polychlorinated biphenyls (PCBs) in their flesh.

MR. SCIENCE. Most Hill staffers (and Congressmen) have legal training; some have studied economics or other fields. All are bright and work like demons, but few have any background in science. When a constituent wrote us an angry letter intimating that the Environmental Protection Agency (EPA) was ignoring his proposed method of measuring asbestos in schools, no one could understand its technical content. Because the staff was convinced that I secretly kept a white lab coat hidden somewhere, they brought the letter to me for translation. Fortunately, I was able to help.

One of the internal memoranda I wrote that year discussed risk assessment. Congress has written unenforceable laws because its members apparently don't understand all the implications of a blanket prohibition. The EPA, for example, must forbid all manufacturing processes that produce *any* dioxin whatever as a by-product. As written, the law doesn't state a permissible trace level. Thus, the EPA will be required, under the law, to shut down more and more factories as analytical techniques improve and EPA technicians succeed in detecting ever smaller amounts of the compound. Eventually, they will have to shut down every petrochemical factory in the country, since it is not possible to remove every last attogram (10^{-18} gram) of dioxin from anything.

Risk assessment offers tools to quantify risk and balance it against costs. But politicians get very uncomfortable when asked to put their names on a law if it leaves them open to such accusations as, "The criterion in this law will generate 260 new cancers per year"—or as a typical political opponent would say, "will condemn 260 children a year to death by cancer."

TOOLS OF THE TRADE. One nice thing about the life of a Hill staffer is the number of organizations that exist seemingly to feed you information. You can obtain the latest version of a legislative measure from the Senate Document Room by asking for the "Bill and Report." There are many other sources of information, including the Library of Congress, which puts out information packages called Issue Briefs that contain copies of recent articles as well as other relevant material; the Democratic and Republican Policy Committees, both of which publish weekly newsletters; the General Accounting Office; the Congressional Budget Office; the congressional caucuses; and the Office of Technology Assessment. Not to mention lobbyists—I spent a lot of time talking to them.

You must give your member a balanced picture of every issue, and you quickly discover that most questions have at least two sides, and usually more. Lobbyists all know that if they lie to you, the word will spread like wildfire and end their influence in a flash. But they are under no constraint to give you a balanced view. One lobbyist will present an excellent argument for his or her position, with iron-clad supporting material. "We're not asking for special treatment; we just want a level playing field," the lobbyists tell you. The trick is to listen carefully, then call up a lobbyist on the other side of the issue, who will arrive with a sheaf of documentation and excellent arguments in favor of that position. "We don't want any special legal favors," the second lobbyist insists, "we just want a level playing field."

Then you check with LAs in other offices to find out which other groups are lobbying for and against the issue, and you talk to them. A call to the Library of Congress should bring you an Issue Brief. Because the Congressional Research Service folks pay attention to whatever issues are current, they are always ready to write custom reports, as well. You call your member's home district office and ask whether organized labor has a position on the issue and whether business interests have gotten in touch about it.

Now you are almost done. You pull up your word processor and write a report that covers all the material, condensing it to a maximum of two pages, with a one-paragraph summary up front, as well as your recommendation on how the member should vote and the reasons for your position.

Then you wait.

Some 1700 bills are introduced in a typical two-year session of Congress. Your member is probably worried about health care, or the budget, or soybean price supports and doesn't have time to read your memo on some other topic. Eventually, though, a window of opportunity will open. It might be the opportunity to co-sponsor a bill, to testify at a hearing, to co-sign a "Dear Colleague" letter, or even to vote on the floor.

On that day, you know the window is opening, so you put the report on the member's desk. When the voting bell rings, you dash down to his or her office. As your member heads for the committee room or the floor, you scurry along, answering questions in more depth. If you work for Bill Bradley—formerly a professional basketball player—you get used to tilting your head back as you walk; the guy is tall. Then you go back to your desk and listen to "the box"—a small radio tuned to an FM channel that broadcasts the proceedings from the Senate floor—to find out if your member followed your advice.

An interesting sidelight on this process is the effect it has on the staffer's personal opinions. I noticed that during my session, most of the Fellows ended up moving toward the political center no matter where they had started.

READING THE MAIL. In my job as an engineer for a large consulting firm, I get lots of mail. If I return from a two-week vacation, I can count on finding a foot-high stack of letters. But when I was an LA in the Senate, I got a foot-high stack of letters about transportation and the environment every day.

Unlike LAs in the House, I didn't go through letters from constituents. Senate staff sizes depend on population, and Senator Bradley had 66 people in Washington, including three legislative correspondents (LCs) who read constituents' letters. When a lot of them poured in on a certain subject, the LCs would simply collect them until there were 35 or so. Then the LCs would come up with an initial tally of what people were saying and how many of them were on each side of the issue.

Letters count, and they count a lot more than prefabricated postcards or obvious form letters—even those with individualized signatures. But every piece of mail represents a voter who cared enough about an issue to get out of his or her chair and walk to the mailbox.

The LC would go over the mail with me. Knowing the senator's feelings on the subject, we'd try to figure what position he ought to take on it. We would draft a letter and take it to the administrative assistant (AA), the head of the personal staff, who must be a kind of field general, strategy director, and *alter ego* to a member of Congress. We might go through a couple of revisions and maybe a staff meeting before the letter reached Senator Bradley. When the senator was satisfied, the LC would crank up the word processor, turn on the auto-pen, and answer the mail.

My own mail, usually from lobbyists, consisted of reports, position papers, and trade magazines. Most of it went straight into the waste basket because the hot information came by courier or from the Library of Congress and the Democratic Policy Committee. Moreover, hot information gets cold with amazing speed on the Hill.

Being a Hill staffer forces you to cope with almost schizophrenic extremes in your personal status. Outside the walls of Congress, I was somebody special. Once, I had to call a New Jersey company that had developed an improved coal gasification technique. I had been given the number of the company's president, so I dialed it. His secretary came on the line.

"May I please speak to Mr. So-and-So?"

"He's in a meeting right now. May I take a message?"

"Sure. Could you please ask him to call George Swetnam, in Senator Bradley's office? My number is..."

"I'll get him for you right away, sir."

Within the halls of Congress, though, my

status was somewhat less grand; in fact, I'd place it just above that of the crickets in the Capitol basement. I spent a lot of time sitting on the cold air register of the air-conditioning system in the Senate Finance Committee hearing room, waiting to call the senator if a particular piece of legislation came up for a vote.

Congress was reworking the tax laws that year, and though taxes weren't my issue, transportation was, and there was a truck tax provision that meant a lot to my senator's state. Everything hinged on the fact that in the 98th Congress, the Republicans controlled the Senate, while I worked for a Democratic senator. My mission was to be ready to call him if the truck tax provision came up for a vote and to brief him as he came through the door about exactly what the vote was on, how various groups stood on it, and the procedural details—to adopt, table, and the like.

The committee had an enormous list of provisions to consider, and the majority (Republican) committee staff director held the agenda for the day. He gave a copy, first, to each senator present, second, to all the Republican staffers, and third, to the press corps. If any copies were left, I could have one.

So long as the truck tax provision wasn't on the agenda, I could go back to the office and work. But if it was anywhere on the day's list, I had to stay. Each day's agenda had two or three times more items than the committee could dispose of, but the chairman could call them in any order he pleased.

The committee room had a large, U-shaped conference table for the senators. My senator's chair was empty, but lightning would have seared my flesh if I had sat in it. On the Republican side of the table, there were chairs for the staff members—one behind each senator's chair. But there weren't any chairs for Democratic staffers, because the TV cameras were placed behind the senators on the Democratic side. Located there, those cameras got nice, full-face views of the Republican senators when they made speeches or asked questions—and showed the hairline or perhaps one ear of the Democratic senators who participated in the action. This arrangement left the cold air register to me. As I recall, it had a waffle-grid top in half-inch squares. I still have traces of that pattern on a tender portion of my anatomy, but it was better than standing.

LUNCHTIME SURPRISES. Every congressional office has an inconspicuous entrance, and it doesn't take long for a new staff member to find out why. One day, I came back from lunch to find the reception area and the hall outside packed with agitated constituents urging Senator Bradley to support their right-to-life agenda. That was not my issue, so I gratefully breezed down the hall to the unmarked entrance. During the very next lunch period, the reception area and the hall were full of agitated constituents urging the senator to support their pro-choice agenda.

One day, our receptionist looked up to see a shabby-looking man enter the office with a battered suitcase, which he set on the floor. "I represent the D.C. Homeless," he told her. "I will be back in 45 minutes

Peter Wallace

with 30 homeless people, and they are going to sleep here in your office until there is action to create shelters here." The receptionist started to tell him that the senator was already a co-sponsor of a bill to provide shelters, but the man turned on his heel and left.

So she summoned the Capitol Police, who arrived in a few minutes and cleared the office while they checked the suitcase, which turned out to contain only clothing. They arrested the man when he returned—without any of the promised demonstrators—on outstanding warrants, telling us that he had spent time in several mental hospitals.

Unmarked entrances, though, weren't always magic. One day I returned from lunch and was immediately grabbed by a secretary. It seemed that 13 mayors of small towns in the same county had arrived unannounced and were sitting in the senator's office. He was out of town, and since I was the LA for environmental issues, it was up to me to talk to them.

They had gotten wind of a plan to build a hazardous waste incinerator in their county and wanted the senator to do something to stop it. After you have worked on the Hill for a while, you learn that there is a standard procedure for this situation. Step No. 1 is to listen very carefully to your visitors' point of view, noting down all of the arguments and making sure you get them right. Step No. 2 is to go through a list of all current proposals before Congress relating to their issue, talking about the prospects for each and its current status. If they have any comments, you note them down, again making sure that you get them right. This all takes a bit of time because there is a lot of boring detail involved; fortunately, you have the details at your fingertips, because that is your job.

Step No. 3 is to assure the visitors that you will present their views to the senator each and every time any measure they are interested in comes up for action. This is an easy promise to make, because that, too, is a part of your job. The delegation then leaves. They are happy that they have been heard and that you haven't fooled them, because they really have been heard, and you really will present their views when the next window of opportunity opens and the senator is ready to listen.

BAD RAP. "Now and then," said Mark Twain, "an innocent man is sent to the legislature." That remark sums up the attitude a lot of Americans have about Congress. In *Hill Rat,* John Jackley, a former congressional press secretary, paints a picture of venality that would make anyone despair. Jackley, who claims that the situation is self-perpetuating, certainly worked for a few self-seeking people, but I myself ran into members who were doing a conscientious, capable job. Congress has its bad reputation for four reasons.

Congress (and government in general) gets the jobs that no one else wants. If there is a profit to be made in any activity, business will rush to fill the gap. But it is hard to make a profit supporting the jobless or fighting drug dealers. So Congress must struggle with such problems as the homeless, the aged, and drugs.

Congress is the arena where power battles are fought. Come to think of it, however, we should probably all be thankful that our legislative affairs are disposed of by committee chairpersons rather than by Somali warlords or Venetian dukes.

When the fellowship year ends

About a third of Congressional Science Fellows contract "Potomac Fever" and never leave the Washington area. This ailment manifests itself as an intense absorption in the governmental process. Some continue to work for Congress; others move to policy-making organizations. Unlike these people, I returned to my job as a consulting engineer, but I have always felt that my Hill experience was extremely valuable.

Mitre's principal activity is technical support to state, Federal, and local government agencies, usually in the executive branch. It was helpful to me to have sat on the legislative side of the issues and to have become acquainted with the atmosphere in which Congress makes its decisions. In addition, the assignment markedly raised my own visibility within the company. What I have found at least as valuable, though, are the skills I had to learn or sharpen. The five that stand out in my memory are juggling multiple tasks; writing; setting priorities; getting to see busy people; and seeing projects in context.

I had been used to juggling two or three projects at a time. In a Senate office, it was common to deal with 15 or 20 tasks at once. I would call somebody about something, and he or she wouldn't return my call for two or three days. The words, "Hi, this is Ms. Freebish at Commerce. What did you want?" would have me frantically fumbling to place Ms. Freebish and recall which issue I had called about. Eventually I took to tacking up a file card for every return call I expected, with the name, issue, and my question as a memory jogger.

Staffers, including Congressional Fellows, do a lot of writing, including press releases, speeches, newsletters to constituents, and memoranda about specific bills. A memorandum to a member of Congress must cover many things. It must be clear and concise because the member doesn't have time to puzzle over an obscure text or to follow lengthy arguments. Most of the time you won't be on hand to add further information, because your memo is likely to be read while the member is on a plane or in a car. I got a lot of practice boiling things down and striving for an efficient presentation.

You also learn to write quickly. Your member may decide to co-sponsor a bill and make a short speech on the floor of the Senate or House to explain his or her position. A floor statement could be needed in 15 minutes, and it must fit your boss's speaking style. Skip Stiles, who worked for Representative George Brown (D-Calif.), told me that he had learned to leave places in his text for Brown to pause, make an appropriate gesture, and go on.

As for setting priorities, everyone on the Hill has a work list twice as long as any human could manage. Working long hours doesn't seem to shorten the list. "As long as you're in by 9 in the morning, you can stay as late as you want"—that is how Hill staffers describe their workday. Bill Taylor, one of Senator Bill Bradley's full-time LAs, told me, "A member of Congress perceives time as a thing that has only two values: Now and Not Yet." Eventually, you learn to set priorities by that standard. "Now" is for the fire that threatens to incinerate you in 15 minutes, or perhaps tomorrow. When you get that one settled, you look at the next disaster in the making.

Busy people are not arrogant—well, not all of them; they just have mailboxes no less deep than yours, as well as a stack of telephone message slips 5 cm thick, just like yours. As a result, you may never graduate from "Not Yet" to "Now" in their estimation, even though you are dealing with an emergency in yours.

One last-ditch technique for getting to see busy people is to walk through their office doors. If they aren't there, you sit or stand outside and wait. When they walk in, they will deal with you just to get you out. Of course, this technique cuts you off from your desk and telephone, so it is reserved for hard cases.

Finally, it proved important to see projects in context. The news media tend to focus on things that are new or make good video footage or good sound bites. If a schedule failure affects a government program, or there is an accident that the program might have averted, it can look as though its fortunes will be very dim or very bright. But the programs that endure are those that affect a lot of people, in a lot of different parts of the country, a lot of the time. It is essential to show benefits as clearly and in as much detail as you can. The same is true when private organizations lobby Congress: the idea you are promoting had better be tied to a clear and demonstrable public benefit. Altruism is nice, but it doesn't get many votes.

—G.F.S. Jr.

People pay little or no attention to Congress except when it does something they don't like. One reason incumbent congressmen enjoy such an advantage is that most of us don't want to be bothered tracking their performance on highway truck taxes, Federal water projects, and the like. Most of the constituent letters I read were filled with anger. "If you don't vote for the Uniform Pass the Bacon Act, I'll vote against you," they threaten. It is hard for members of Congress to attract voters by their overall performance, because so many people focus on one pet issue; in fact, it is hard to make everyone happy even on one side of one issue.

A lunchtime friend of mine has a simple test for any national policy issue: does it help or hurt him personally? That is all. Members of Congress therefore keep targeted mailing lists and send environmental newsletters to those who write letters on the environment, health care newsletters to senior citizens, and "The Pork I Got for Our District" newsletters to just about everyone in it.

It is tough to be courageous in the political arena. Pico Iyer, a South American writer, quoted a Paraguayan legislator to the effect that "A good politician makes lots of enemies. A bad politician is surrounded by friends." This is no less true in Washington. In the end, that great truth explains why Congress is the way it is. If enough citizens tracked their representatives on their whole records—or if people were willing to face up to the realities of deregulation, the job impact of the Endangered Species Act, the consequences of saving the savings-and-loan associations, and the cost/resources tradeoff in national health care—then letters to members of Congress would be more thoughtful and less prone to demand quick fixes. Were this to happen, our senators and representatives would be a lot more willing to make hard decisions.

Now where is that report on how to change human nature?

TO PROBE FURTHER. Although there are at least two good books about the job of a Hill staff member, they paint strikingly different pictures of the process. What you see on Capitol Hill depends a lot on who you are and what you expect to see. If you are interested in applying for a Congressional Fellowship, you could do a lot worse than read both books.

Eric Redman's *The Dance of Legislation* (Simon & Schuster, New York, 1973) focuses on a specific bill, following the rise and fall of its fortunes as it struggled to become law. *Hill Rat: Blowing the Lid Off Congress* (Regnery Gateway, Lanham, Md., 1992) is by John L. Jackley, who was a press secretary rather than a legislative assistant. In the House of Representatives, however, staffs are small, and Jackley was deeply involved in the business of the member's office.

Former Congressional Fellows are another good source of information. Tom Suttle of the IEEE's U.S. Activities Board has a selection of final reports from them, and he will supply this material to IEEE members who are seriously interested in a Fellowship.

Again, it is wise to read more than one report because the experience and specific duties of Fellows vary a great deal. A lot depends on whom you work for and the terms of your assignment.

ABOUT THE AUTHOR. George Swetnam (SM) has been on the staff at The Mitre Corp., McLean, Va., since 1969. During his years there, he has worked—in both the United States and the Federal Republic of Germany—on urban mass transportation, geothermal energy systems, weather forecasting, and air traffic control. He is currently assisting in developing a computer system for managing air traffic at busy airports. Before joining Mitre, Swetnam spent nine years at Bell Telephone Laboratories, where he worked on the development of the No. 1 and No. 2 Electronic Switching Systems, a field in which he holds two patents.

Multimedia's push into power

Integrated with both visualization and advanced document retrieval, this novel approach is being demonstrated in Germany

The supervision of highly automated industrial plants, of the kind to be found in manufacturing, chemical processing, and power generation, is already highly centralized. But pressures both economic and ecological are building for improved, more powerful supervisory and control systems. The task is daunting, but can be accomplished by a system that integrates two new technologies—visualization and multimedia—and encourages collaboration among operators with different specialties.

At present, there is a growing gap between those overseeing automated processes and the processes themselves, a growing inflow of data, and a growing specialization of activity that precludes a grip on the big picture. The level of production and product quality are increasingly becoming the operators' responsibility—they establish setpoints in line with production goals and then monitor and, in case of deviations, troubleshoot, but seldom is there an opportunity to intervene manually in the plant's operation. The information they need for decision-making is gathered from a multitude of sources by the central control room, from which thousands of measurements and, in turn, hundreds of actuators in the plant can often be manipulated. Yet the control room is frequently a clean, air-conditioned place sealed off from the sights, sounds, smells, and other sensations produced by the plant or by the process.

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ABB Power Plant Control Division

Moreover, all these plants require a certain level of specialization—in process control, in maintenance, and in production planning—and the specialties are often divided among operator staff handling different parts of the process in different places. The "runners" may be in the plant, operators in the control room, and other staff members in offices.

The power plant is the specific focus of a prototype supervisory control and data acquisition (Scada) system that integrates multimedia and visualization. Intended for a coal-fired power plant, the prototype was developed in 1992 by researchers at ABB Corporate Research in Heidelberg, together with practitioners at ABB Power Plant Control in Mannheim, Germany. The prototype equips a control room with wall-sized screens and the operators with a mouse for use on a window-based interface. Other features are new forms of visualization of process information, access to hypermedia documentation, interactive video facilities, and videoconferencing [Fig. 1]. Special attention has been paid to the seamless integration of functions and to ease of navigating among the varied forms of information and varied media that are used.

The goal of ABB's work in this area is to lighten the operators' workload and simplify the cognitive demands made on them, and hence increase the availability, economy, and safety (ecological and otherwise) of plants and production processes. Today, operators are really the ones who "integrate" and work with the information from the process control system, the documentation, and many other sources.

The standard situation in process supervision and control is quite a contrast. For example, a message from a malfunctioning component may pop up on the operator's console, usually in a longish alarm list. The operator calls up a corresponding process and instrumentation diagram, generally by entering a code on a function keyboard, and tries to analyze the situation. He or she may have to grab the folder in which the operation manual is kept so as to look up a maintenance procedure or maybe grab another folder containing a logic diagram so as to map this information against the actual signal values shown on another computer display. A runner in the plant calls the control room on his radio about, say, the consistency of some material. The operator now mentally relates this verbal input to information on temperature, pressure, and other factors from the process control system.

Evidently, much of the information from the process and the process control system is carried by different media. Cathode-ray tube (CRT) screens display textual and graphical data, including status messages, alarm lists, process and instrumentation diagrams, and several types of line charts. Radio and telephone communication occurs within the plant and to the outside over equipment independent of the process control system.

Video monitors show pictures from cameras positioned inside the plant for security as well as process-monitoring purposes [Fig. 2]. The cameras' viewing angle or zoom can sometimes be remotely controlled, and the units may be hooked up to a TV monitor directly or be switchable remotely to share a dedicated monitor. Folders hold technical documentation and manuals containing operation and maintenance information for the plant and the process, and are sometimes kept outside the central control room. Typically the operator uses an assortment of devices for direct interaction, such as keyboard, mouse, and telephone.

The task of watching and reacting to all

Defining terms

Hypermedia: multimedia plus some structural information that links the different media to make it possible to navigate through them all to access data from them all—for example, from a word to a drawing to a maintenance instruction to a video that shows how to fix a problem component.

Mass data display: a new type of display that makes it easier to comprehend the meaning of a large number of data points from dynamic processes. Each data point is represented by an animated line or other graphical element, which can change over time in size, tilt, color, or whatever. The arrangement of all the graphical elements represents the process topology—steam-water cycle or conveyor belt layout, for example.

Multimedia: information coded or represented in various media such as text, graphics, animation, video, or speech.

Process control system: typically a distributed system of programmable logic controllers, linked by a communication bus, or a system of central processors with remote input and output units. The system lets the operator observe the process and control the plant by providing the system with new setpoints.

Process and instrumentation diagram: a drawing or display of the arrangement of plant components (like pumps and valves) and the flow of some process medium (like water) and the measuring instrumentation (such as flow meters).

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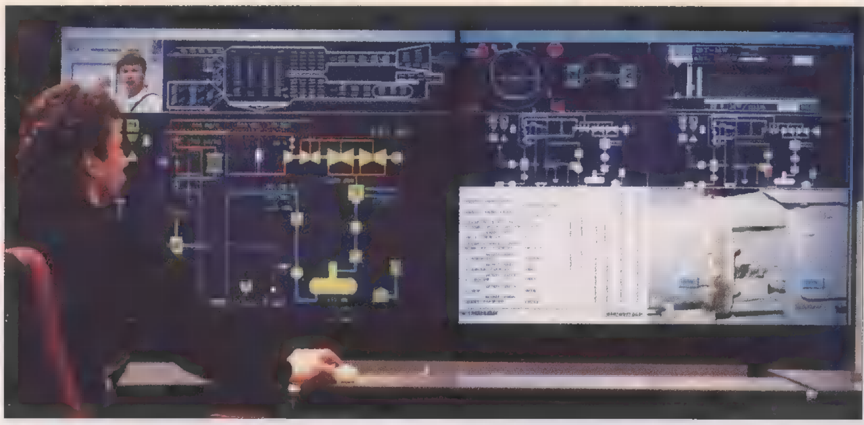
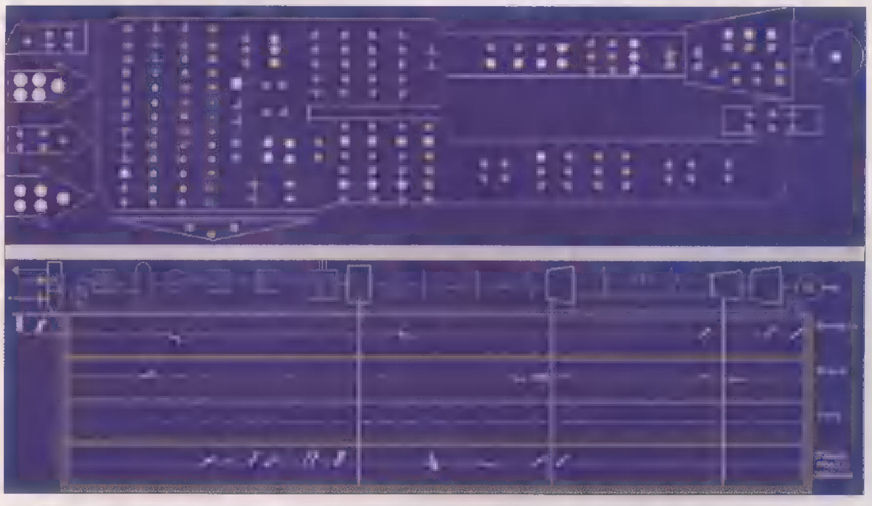


ABB Corporate Research (photos)

[1] A modern control room with large screens glows with new forms of visualization, integrated multimedia, electronic documentation, and telecommunication facilities. This system lessens the demands on operators who have to assimilate and act on incoming information. Suppose an alarm message comes up: the operator can call any process or instrumentation logic diagram suggested and is at once given a maintenance procedure from the integrated operation manual or from a live video camera in the plant. If more help is needed, a videoconference with outside experts is at the tip of the finger, more evidence of the information sharing encouraged by the system.

[2] This control room's information media have not been integrated. Textual and graphical data appear on cathode-ray tube screens; radio and phone messages link persons in the plant to each other and to the outside; TV monitors show pictures from cameras inside the plant; and good old paper stores technical documentation and operating manuals in a multitude of folders.



[3] Mass data displays attach graphical elements, such as circles to incoming plant data and use the elements to portray ongoing process activity, albeit schematically. Here, a steam-water cycle topology is tracked by circles [top], while lines tabulate energy transformation [bottom] from coal to heat to electric power [horizontal axis] against flow, temperature, or other types of measurement [vertical axis].

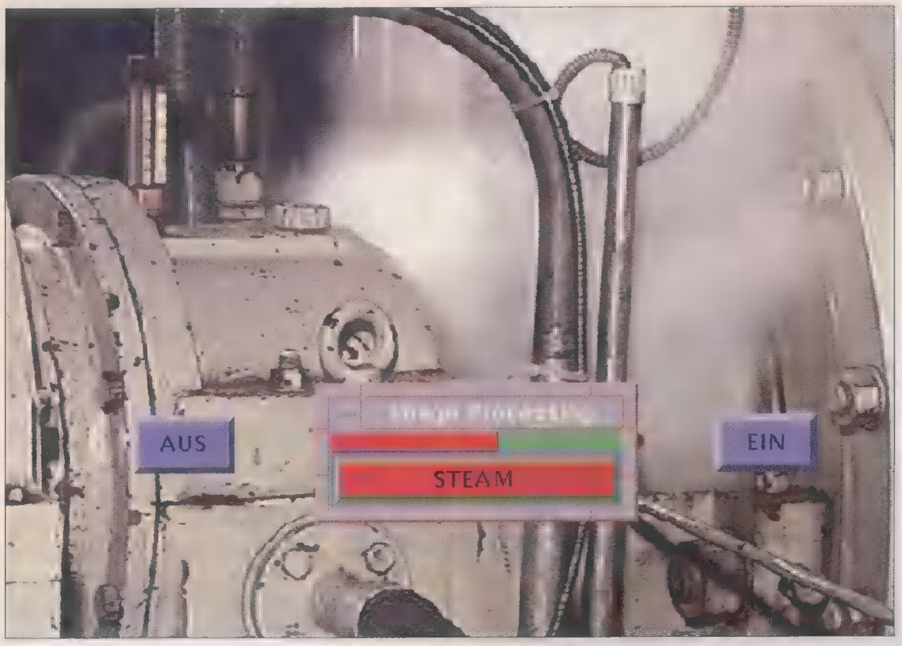
the data spun off by a large dynamic process can be eased, however, if the technologies of visualization and multimedia are integrated in a way that allows operators to run the process control system interactively.

The prototype at ABB is based on workstations running the Unix operating system and the X11/Motif window and graphics system. The multimedia hardware consists of extensions that are widely available on many platforms—digital audio, digital video from several compression schemes—and the possibility of displaying analog video as high-quality, 24-bit images at television frame rates. Such graphical hardware also features "overlay" planes in that it can draw graphics over the live video picture—a capability useful for the multimedia functions discussed later. The reason for choosing workstations over PCs lies in the more powerful processors (reduced-instruction-set central processing units) as well as the more powerful graphics and networking capabilities—including the Unix operating system and the X11 window system.

NOVEL VISUALS. One of the chief tasks of someone engaged in supervising industrial processes is ensuring their safe and economic operation. Especially with a thermodynamic process like power generation, continuous assessment of the state of the process and early detection of impending failure, rather than just reaction to disturbances, are of supreme importance. The usual power plant has more than 10 000 binary and a couple of thousand analog measurements that must be observed and understood if the right decisions are to be made. Of course, the hierarchical aggregation of alarms and emergency shutdown, while mandatory, are seldom the best way to meet the aforementioned requirements.

The deluge of dynamic data produced in the plant is too much for the human operator to monitor, let alone process. Before the cathode-ray tube became the basis for process supervision and control, control rooms were equipped with large control boards showing the process and measurements, and human operators assessed the state of affairs in the plant by scanning the dials, meters, and patterns of indicator lights. Upon spotting an unfamiliar pattern, an operator would step closer and read the specific values from the process and instrumentation diagram on the control board.

Figure 3 shows how this concept is applied to CRT-based operator stations to achieve a new type of process overview display. Each graphical element of the dis-



[4] With integrated and interactive video, the operator not only "sees" the process directly, as with this defective feedwater pump, but can react by applying image processing and/or by controlling components of the process by touching "buttons" superimposed on the video image.

play—a line, circle, or square, say—represents a value from the process. Each element is constant in shape but dynamic in behavior: lines may rotate or change thickness according to a deviation from a reference value or a rate of change (process transient), while circles may change in size or gray scale or position, or any combination of such variables. The arrangements of the graphical elements can match the topology of the process or be tabular. They may reflect the steam-water cycle of the power plant, in the first case, or be grouped as tables of process measurements of particular types, such as temperature, pressure, control, and set points.

The name given to this type of display is a mass data display. Its design draws on the fact that the human eye and brain can process hundreds of graphical elements in parallel yet easily pick out any that are abnormal. In a steady state the mass data display should have a visually harmonious appearance: the graphical elements should be in step, with the lines, say, all oriented horizontally. Deviations in any given pattern indicate disturbances. This approach is based

Nuclear power plant control in transition

Licensing and safety requirements preclude radical change in the design and operation of nuclear power plants. Consequently, their control rooms are still based on 20- and 30-year-old technology, while other industries have progressed to full digital instrumentation and control.

Favoring an evolutionary approach, ABB Combustion Engineering Nuclear Systems has developed a digital control complex using only proven commercial hardware. The design retains the current role for the operator, emphasizes lessons learned from utility operating experience, and builds on proven aspects of conventional control room design. The ABB control complex has as a result succeeded in providing a licenseable transition to the computer-based control room.

The architecture emphasizes safety and reliability. Redundant, independent, and diverse instrumentation and control systems are used. Plant monitoring, for example, employs two independent but parallel information display systems driven by the same plant sensors. One provides a plantwide hierarchy of color graphic screens (cathode-ray tubes) and extensive data-processing features at each control panel. The other is a simpler but more stringently qualified system, one in which electroluminescent flat panels present key process values at fixed locations on control panels.

The two systems employ redundant computers, segmentation, optical-fiber communications, and touch-screen displays. However, they use different hardware and software, and are configured by separate design teams. Together, they prevent the loss of information due to single failures, they eliminate the need for "backup" displays, and they minimize the risk of common-mode failures. Equivalent techniques have also been applied to the component control and the plant protection systems.

In keeping with an evolutionary approach, the use of automation in the control complex is limited to established plant control and safety applications, leaving the operators actively in control. Digital technology is applied to enhance the reliability and usability of indicating and control functions. Computers, for example, take a lot of the toil out of establishing a parameter value; they verify and validate low-level data from multiple sensors and finally aggregate them to produce a single representative number. Presented with preprocessed information rather than raw data, operators do less work to obtain trustworthy information. Similar processing of alarm inputs not only eliminates false alarms but also reduces the number of alarm tile locations on the control panels by 60 percent [see photo].

Costs of construction, operation, maintenance, and modification are reduced. Compared with conventional designs, 70 percent less copper cabling is required, and there are 70 percent fewer indicating devices on the control panels. Because of the inherently higher reliability of digital components and the use of self-testing features, operators and technicians need to perform surveillance less often. Because components are standardized and equipment is modularized, parts inventories, training requirements, and repair times are reduced. Changes and upgrades are readily accommodated by software-based displays and an open system architecture.

The system is the first integrated control complex based on digital protection, control, and monitoring systems for pressurized-water reactors to be approved by the U.S. Nuclear Regulatory Commission.

—Robert Fuld

ABB Combustion Engineering Nuclear Systems

In the Nuplex 80+ Advanced Control Complex, an integrated overview of process status is visible from anywhere in the control room, presenting continuous safety and plant status information to the operator. Also shown in the photo is the master control complex.

The author is a human factors specialist and consulting engineer at ABB Combustion Engineering Nuclear Systems in Windsor, Conn. He is also a former nuclear power plant operator.

on research at ABB and at the technical university at Clausthal, Germany, which compared the reaction times and behavior of operators detecting faults in the process control system by means of, on the one hand, the mass data display and, on the other, traditional process and instrumentation diagrams. The reaction time to the mass data display was significantly faster than that associated with the traditional display.

A key requirement is the ability to gain access through the mass data display to related, more detailed information for closer inspection—in short, the ability to navigate between different representations of the same information. In the mass data display, selecting any graphical element or area can be made to yield the following information:
- The name(s) and the value(s) of the process measurement(s).
- A time line of each process value, possibly in line graph form.
- A process and instrumentation diagram placing a measurement in its process context (the analogy is with the operator stepping nearer a conventional control board and taking a closer look).
- Other information on this measurement from the documentation, including supplier data, sensor type, mean time between failures, or commissioning data.

INTEGRATION OF MULTIMEDIA. A central control room is generally proofed against the heat, noise, or other pollution from the plant and the process. Only experienced operators can recall such details as the size of pipes in the plant, and relate this to a "feel" for the flow rate or pressure a certain pipe might withstand.

All the same, examples abound of the advantages an eye or ear for an industrial process can bring to its control. Seeing a part of the process or hearing the noises it makes can convey more information to some operators than sensor data shown on the control system console. Of course, the opposite can be true in other situations. Care therefore must be taken in selecting when and how to apply live video, to name one form of input.

The ABB prototype system boasts several of the features of an integrated and interactive video system. For one, it can select video sources from other process displays. For instance, camera icons in the process and instrumentation diagrams give direct access to the corresponding camera in the plant, whether it is a typical TV camera or one sensing in the infrared or X-ray spectrum.

The system can also analyze video data by means of image processing and recognition. The video picture or parts thereof thus become sensor data, on the basis of which further actions can be started. For instance, in the simplest case, alarm messages may be generated. Of course, the video could also be monitored in the background and the operator notified if a specific change, like an undue evaporation of steam, occurs.

The system also provides operation buttons overlaid on the video picture to assist the operators in direct switching of a failing component [Fig. 4]. As in hands-on control, this action can be carried out without calling other process displays. In case such a component is part of a more complex control circuit, the appropriate control display can be called up directly, so that the operator can assess the context or the impact of the control action.

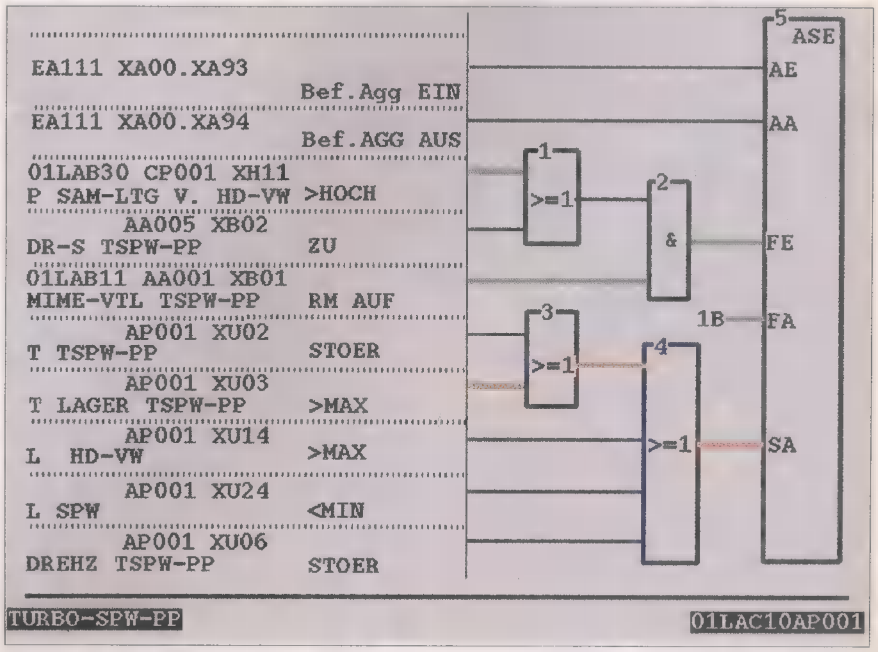
Furthermore, the system enhances the video with information from the process control system. For example, an infrared video picture of a pump showing the exact distribution of oil temperatures around the shaft could be enhanced by superimposing the values of flow and pressure measurements, or by overlaying the schematic diagram of the switching logic. These comparisons would help with control-related decisions, like how to start this pump from a hot standby when the oil temperature in the pump's gear box is within a given range.

ELECTRONIC DOCUMENTATION. Another example of the helpfulness of pooling background with actual process data arises in the domain of on-line electronic documentation. Electronic documentation systems enable operators to search and retrieve information easily and efficiently in case of failing components. Figure 5 illustrates how the integration of electronic documentation with the process control system makes it much easier for the operator to spot a failure early on. In the case of a process disturbance, the operator may need to analyze a signal flow in a logic diagram. The appropriate diagram is called up and the states of the signals are displayed as color codes. Far less time is needed to look up either the diagram or the actual signal states.

Documentation for a complex plant today may be produced directly from the logic diagrams, mechanical design drawings, or whatever of the engineering process, or it may be derived from the process of designing a plant, namely, from sources like operator manuals and maintenance guidelines. However, in most cases even this kind of information from computer-aided design, engineering, or manufacturing systems is usually printed, and is later used as paper-based documents.

Hypermedia documentation systems—text, drawings, plus audio and video and combinations thereof—in addition to the above features allow the user to navigate easily within the electronic documentation. They provide optimal support for many lifecycle phases of a plant—commissioning, operator training, operation, and maintenance, to list a few.

Many applications are possible. An animation with an explanatory audio track might illustrate startup procedures one step at a time. A chart showing the optimized design of the burning chamber of a gas turbine might be accompanied by a video that shows how the fuel nozzle is repaired. These scenarios need not be limited to the control room operators' stations only—text, graphics, audio, and video can also be transmitted back and forth between



[5] For the operator, integrated electronic documentation makes short work of looking up not only process and plant schematics, but also the state information on signals and components that appears as overlays in these schematics. The documentation shown here indicates that the temperature of the bearing in the defective turbine-driven feedwater pump shown in live video in Fig. 4 is excessive [the line T LAGER TSSW-PP >MAX] and is coded yellow. Logically combined with other signals in comparators, this signal would then lead to an emergency shutdown [SA, bottom right].

Human factors guidelines for electric utilities

The introduction of digital control systems into electric utility power plants raises new and complex issues in relation to human factors. Challenges include arranging this equipment effectively for control room operators and how best to exploit advanced cathode-ray tube (CRT) graphics capabilities.

Experience at electric utilities has shown that engineering with human factors in mind generally makes plants safer, improves availability, and extends equipment life. As a long-time sponsor of human factors research, the Electric Power Research Institute (EPRI) in California has recently issued guidelines to help utilities incorporate human factors into the design of control rooms for fossil-fueled power plants.

The guidelines help utilities do the following:

- Design facilities so that the environment supports system operation.
- Place components so that operators can perform their jobs more efficiently and with less opportunity for error.
- Make control functions natural and easy to understand.
- Position control devices to simplify operations.
- Use control devices that will withstand the rigors of operation.

The institute's guidelines apply to both workspace and equipment layout. The advice on workspace covers climate, noise, lighting, and visibility; physical access and traffic; workstation and console design; seating and desks; and support facilities and safety equipment. The advice on equipment layout covers push buttons, switches, rotary controls, multicontrol modules, and control coding; visual displays, legend indicators, and annunciator tiles; counters, recorders, and analog meters; digital displays, auditory signals, alarms, and labeling.

Good displays inform the operator clearly of what he or she needs to know. In fact, the proper use of color, display organization, and menu design, as well as the choice of the strategy for grouping the controls, can enhance the operator's performance on the job. For instance, after upgrading several control rooms without taking human factors assistance into consideration, one utility ran into a whole range of display-related problems.

At the system level, there were no displays for certain modes (such as startup), updates occurred too infrequently to show trends, and operators lacked confidence in the information displayed. Screen hardware could only show text, not graphics. Screen layouts were sometimes too dense, and certain colors on some systems could not be told apart. Menus were unnecessarily long and without groupings in too many cases. Some paging and scrolling procedures were difficult to learn. Nuisance alarms and lack of an explanation for alarm sequence data were typical problems.

The institute's guidelines can now enable utilities to avoid or at any rate to remedy these problems. Entitled "Human factors guidelines for fossil power plant control rooms and remote control stations" (EPRI document No. EPRI TR-101814), the guidelines also include practical advice on winning acceptance of new equipment and improving performance. —*Roy R. Fray*

The author is manager of simulators and training at the Electric Power Research Institute (EPRI), a research consortium for the U.S. electric utility industry, located in Palo Alto, Calif. Requests for the guidelines should be directed to the EPRI distribution center, 510-934-4212.

the control room and ■ portable station at a field engineer's site.

In many of its aspects, process supervision and control is ■ matter of team work, even though the trend in many plants is to a smaller staff of more highly qualified individuals having heavier responsibilities. A growing charge on ■ modern supervisory control system is the support of communication between these experts. Domains of expertise range from control theory to knowledge of the process and the equipment, from logistics to maintenance to product marketing, and possibly much more.

For an expert team, large screens can become a common information exchange and working area. The assumption is that all members of the team can view and interact with this shared space on equal terms or by set rules. For example, one operator may take ■■ item from his own screen and display it on the large screen for general discussion. Or several persons may "point" to pieces of information on the large screen and highlight or initiate changes there. Pointing devices and technologies that identify and "read" an individual operator are crucial but need work. More development in areas like portable mice, speech input, and eye and gesture tracking is still necessary for satisfactory applications in process supervisory and control environments.

Given the globalization of production processes, the ability to collaborate over a wide area cannot but gain in importance. Not only may the design and engineering for a given plant arrive from a different part of the world, but plants for the same product may also be spread all over the world. Telecommunication facilities are growing rapidly and can quickly be linked up to process supervision and control. Integrated videoconferencing implies more than the interchangeability of camera pictures; it also means the opportunity to build a shared space, in which more places than just the control room have access to process data plus all the necessary background information from the documentation and other support systems.

Consequently, the large screens in the control room may become shared virtual whiteboards for the operators there, while field personnel outside gain interactive access to much the same information through portable equipment like the cameras that a maintenance engineer wears with his safety hat.

Since 1992, the ABB Power Plant Control Demonstration Center in Mannheim has given hundreds of demonstrations to visitors, and has also been used for detailed investigations. As far as costs are concerned, the enhancement of ■ state-of-the-art supervisory control and data acquisition system with integrated multimedia and visualization capabilities discussed here is expected to be within reach of most companies.

BEST HUMAN FIT. As for the future, given the rate of development in the enabling technologies—the processing speed of computer hardware, software complexity, productivity and quality, telecommunications, and digital audio and video—the goal must be the fullest possible exploitation of human faculties for processing information. Here priority should be given to a natural style of interaction with the supervisory and control system. Probably the most important areas to explore are speech generation and recognition, handwriting, and gesture recognition for data and command input. Furthermore, virtual reality, which is just beginning to emerge, has its own potential applications in process supervision and control systems.

TO PROBE FURTHER. Articles on advanced supervisory and control applications appear in the proceedings of the 1993 IEEE Conference on Systems, Man and Cybernetics, held in Le Tourquet, France, in October 1993.

The proceedings of Association of Computing Machinery (ACM) conferences in the last few years also are an excellent starting point for the issues of this article: visualization, multimedia, and collaborative systems. The *Communications of the ACM* had ■ digital multimedia systems issue in 1991.

An excellent introduction to the topic of information displays and visualization can be found in *Semiology of Graphics* by Jacques Bertin, University of Wisconsin Press, 1983.

On the various topics covered in this article there have been many related contributions in *IEEE Spectrum*, including "Interactive multimedia," March 1993, pp. 22–39; "Virtual reality is for real," October 1993, pp. 22–39; and "Control room design: lessons from TMI (Three-Mile Island)," by Lewis F. Hanes, John F. O'Brien, and Raymond DiSalvo, June 1982, pp. 46–52. ◆

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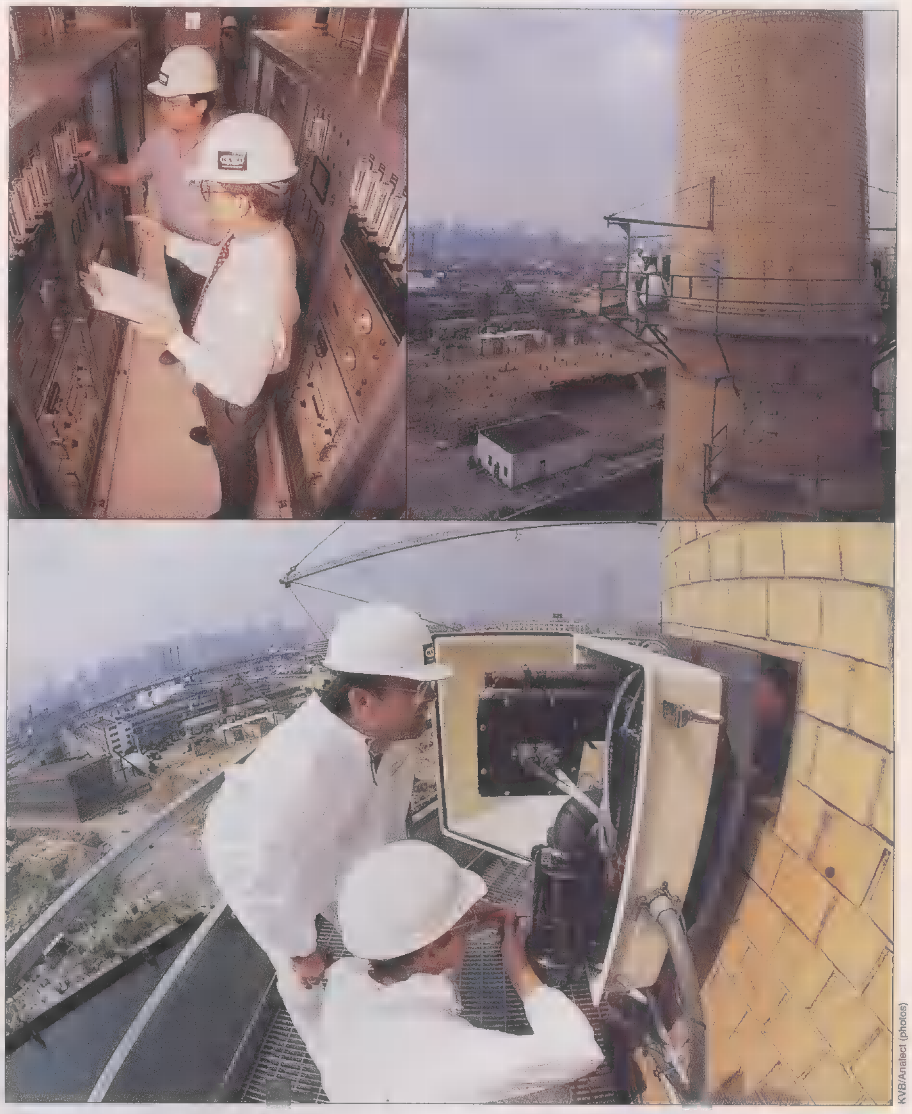
A slow start for emissions trading

Utilities and regulators are blaming each other because less trading in pollutant emission allowances has occurred than was expected



The only evidence that combustors may not be exceeding the emissions limits imposed by the Clean Air Act amendments of 1990 is compiled by so-called continuous emissions-monitoring systems (CEMS). Installed in smokestacks, they analyze the flue gas, keeping a running tally of emitted particulates and pollutants. For utilities, the principal monitored pollutant is sulfur dioxide. However, other organizations also must use CEMS. In the upper left-hand photo, technicians record readings from monitoring equipment located at a municipal waste combustor in New York City. The system monitors escaping visible emissions—smoke and particulates, mainly—by recording their attenuation of a beam of light passing across the inside of the chimney. The other two photos show the monitoring system at the time it was being installed.

KVB/Analect (photos)

Over two years after the start of emission allowance trading, the jury is still out on the bold and provocative U.S. experiment.

Amid publicity not often seen in the staid electric utility industry, the plan was incorporated into the Clean Air Act amendments of 1990. The underlying idea is simple but innovative: rather than being forced to reduce generating plant emissions to some level decreed by the Government, utilities have been allotted a certain number of credits, or allowances, each entitling its bearer to emit a ton of sulfur dioxide. From next year on, the United States' 110 "dirtiest" generating plants will be permitted to emit only as much sulfur dioxide as their utility operators have allowances (emitting more could incur fines of $2000 for each illicit ton). Most importantly, the credits can be traded among utilities or bought at public auction, giving them more flexibility and autonomy in how they comply with emission limits that will become increasingly stringent.

The benefits of such a system are many, and not all are immediately obvious. Because of differences in state regulations, plant efficiencies, electrical demand, and the costs of labor, equipment, and fuels, the annual cost of "cleaning up" emissions from power plants varies significantly from utility to utility in the United States. In a system in which allowances can be traded, utilities that can significantly clean up their plants' emissions at relatively low cost can do so, retaining allowances they may then sell to utilities whose clean-up costs are much higher. Both groups thereby reduce the cost of complying with sulfur dioxide restrictions. Cleaning up can be accomplished by any of several means, including switching to fuels with less sulfur or installing "scrubbers," equipment that removes pollutants from the smokestack flue gases.

In 1989, under contract to the U.S. Environmental Protection Agency, ICF Resources Inc., a Fairfax, Va., consulting firm, estimated that allowance-related cost savings could be as high as $2 billion a year. Such financial incentives, many analysts believe, will hasten development of advanced pollution-control technologies. Although allowance trading is now being applied mainly to the control of sulfur dioxide emitted by U.S. power plants, many experts have high hopes that the program will be a template for the development of similar ones to reduce the cost of controlling nitrogen oxides, industrial

Glenn Zorpette Senior Associate Editor

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solvents, and, perhaps someday, worldwide emissions of greenhouse gases like carbon dioxide. To Carlton W. Bartels, director of Cantor Fitzgerald Environmental Brokerage Services in New York City, allowance trading is "probably the best innovation in environmental regulation in decades," and he's far from alone in the conviction.

"The fact is, we do have a scarce resource: the ecological ability to absorb pollution," said Bartels. "We can have the Government mete it out, which is economically inefficient and has led to a terrible allocation of our money spent on environmental cleanup. Or we can place the decision-making on the people who know the options—rather than someone in Washington trying to figure out the options."

Nonetheless, almost all involved agree that the rate of trading among utilities is not as high as had been expected when the concept was being discussed during the formulation of the 1990 Clean Air Act amendments. "It's like a party that no one's coming to," said Douglas R. Bohi, an analyst and director of the Energy and Natural Resources Division at Resources for the Future, a Washington, D.C., think tank.

Trading formally began in 1992. But as of the end of last April, according to the Environmental Protection Agency (EPA), there had been only about two dozen trades of 10 000 or more allowances apiece. This is not nearly enough to realize the kind of financial savings originally envisioned. The anticipated brisk, routine buying and selling of allowances at the Chicago Board of Trade and on the New York Mercantile Exchange has not transpired. What's more, only one utility has opted to rely on allowance purchases as the heart of its strategy for complying with the initial phase of Federal clean-air regulations.

Some observers believe this inertia signifies deep-rooted problems. "Regulators are not providing active encouragement to utilities to engage in trading, and utilities are behaving as if trading were restricted to intrastate transactions," Bohi wrote in a recent edition of *The Electricity Journal*, an influential industry publication. "If this pattern of behavior continues, the emission allowance trading program will prove to be considerably less successful than expected when it was formulated," he concluded.

Allowance brokers and utility officials incline to a different view. "You have to ask yourself, what was the purpose of the trading system," said John Palmisano, president of Aer*x Inc., a Washington, D.C., emissions allowance brokerage and consulting firm owned by the gas marketing company Enron. "Was the purpose of the system to create lots of trades? Or was the purpose of the system to create a cost-effective complement to the regulatory system, and lower compliance costs with the same, or better, outcome?"

HALF THE SO_2. Sometimes lost amid the discussions of market behavior and economics, cost projections, and regulatory impacts is the program's fundamental objective: reducing the amount of sulfur dioxide emitted into the air by investor-owned U.S. power plants, which account for nearly 70 percent of the country's airborne SO_2.

As was enacted in the Clean Air amendments, the emissions-reduction program has two phases. The first, which lasts five years from next Jan. 1, affects only 261 boilers at the 110 power plants identified by the EPA as having the highest emissions. The goal of the first phase is to get the annual SO_2 emissions from this group of "dirtiest" plants down to about 5.7 million tons.

The second phase, which begins on Jan. 1, 2000, will expand the program to essentially all fossil-fuel boilers with generating capacity of 25 MW or more, of which there are some 2200. The goal of this phase is to lower the total SO_2 emissions from the U.S. plants involved to about 9 million tons a year, about half what they were in 1980. Once reduced to this level, electricity generators will be required to maintain it indefinitely, regardless of capacity additions.

Each affected boiler at every utility has a 30-year allotment of allowances, to cover the first phase and the first 25 years of the second. Another year's worth is added as one is completed, so there is always a 30-year supply. Allowances are issued by the EPA in vintages, which can be used any time during *or after* a specified year. This arrangement not only allows a utility to "bank" any unused allowances for future use, it has also stirred expectations of a futures market in allowances, which has, however, been slow in getting off the ground.

Befitting their ephemeral nature, allowances officially exist only as stored data in a central computer system at the EPA in Washington, D.C. After a long delay, this Allowance Tracking System was brought on-line last spring.

At first, buyers and sellers had few ways of finding each other. Then brokers and various trading systems appeared that enabled those seeking or selling credits to post their propositions bulletin-board style. Besides Aer*x, they include: the Environmental Brokerage Services department at Cantor Fitzgerald, the world's largest auctioneer of Government debt and related securities; Clean Air Capital Markets of Washington, D.C.; Emission Exchange Corp. of Denver, Colo.; and the Terra Group of Washington, D.C. In addition, a number of utilities have departments or subsidiaries set up to broker their own (or other) deals; they include PSI

Major trades in emissions allowances announced since 1992*

Buyers and...	...home state	Allowance trades in thousands	Home state of...	...seller
Carolina P&L	North Carolina	150	New York	Centre Financial
Centre Financial	New York	150	Kentucky	Henderson Municipal P&L
Illinois Power	Illinois	125 (a)	Unknown	—
SCE&G Co.	South Carolina	112	Ohio	American Electric Power
Illinois Power	Illinois	90	Unknown	—
Illinois Power	Illinois	80	Illinois	Central Illinois Public Service
Carolina P&L	North Carolina	80	Ohio	American Electric Power
Illinois Power	Illinois	75	Wisconsin	Wisconsin Electric Power
Wisconsin Electric Power	Wisconsin	75	Illinois	Illinois Power
PSI Energy	Indiana	60.5	New York	Centre Financial
Centre Financial	New York	60.5	Texas	Texas Utilities
Wisconsin Electric Power	Wisconsin	50 (a)	Connecticut	United Illuminating
PSI Energy	Indiana	37	Wisconsin	Wisconsin Electric Power
Illinois Power	Illinois	35	Wyoming	PacifiCorp
AMAX Energy	Indiana	30 (a)	New York	Long Island Lighting Co.
Duquesne Light	Pennsylvania	25 (a)	Wisconsin	Wisconsin P&L
Ohio Edison	Ohio	25	Indiana	Alcoa Generating
Southern Company	Georgia	25	New York	Cantor Fitzgerald
Cantor Fitzgerald	New York	25	Ohio	Cleveland Electric Illuminating
Cleveland Electric Illuminating	Ohio	20	New York	Cantor Fitzgerald
Cantor Fitzgerald	New York	20	Georgia	Southern Company
Mississippi Power	Mississippi	20	Ohio	American Electric Power
PSI Energy	Indiana	14.5	New York	Centre Financial
Centre Financial	New York	14.5	Wyoming	PacifiCorp
Tennessee Valley Authority	Tennessee	10	Wisconsin	Wisconsin P&L

Source: various issues of *Compliance Strategies Review* (Fieldston Co.); Allowance Tracking System, U.S. Environmental Protection Agency

* No data after April 1994 were used. Environmental Protection Agency allowances are not included. P&L = Power and Light

(a) Some or all of the total are options; in the case of the Connecticut trade, the total amount has not been determined because the time period of the options is indefinite.

Energy (formerly Public Service Co. of Indiana) in Indianapolis, and Wisconsin Electric Power Co. in Milwaukee. Brokers charge various fees for arranging a deal; Cantor Fitzgerald, for example, generally receives $1.75 per allowance.

To stimulate trading and help set prices, the EPA withholds some allowances each year—150 000 in the first phase, 200 000 in the second—and auctions them off along with any others put on the block by electric utilities and other sellers. (The numbers amount to under 3 percent of the total allowances issued in any year.) Proceeds from the auctions are distributed among the utilities from which the allowances were originally withheld.

After the withheld allowances are auctioned off, others put up for sale privately are sold. For this second auction, bids to buy and offers to sell are submitted in advance. Buyers indicate how many allowances they want, and what they are willing to pay (sellers indicate what they are willing to sell for). The auctioneers take the highest bid and match it with the lowest offering price, and the transaction is completed at the bid price. The next lowest offering price is then matched with the next highest bid, and so on. In effect, the highest bids to buy get highest priority.

At the auctions, which are actually carried out by the Chicago Board of Trade, anyone may buy allowances, enabling speculators to look for deals with an eye towards making ■ profit if prices rise. Also, environmental organizations and even concerned citizens can, in effect, buy the right to have a ton of SO_2 kept out of the atmosphere (the number of allowances sold for environmental reasons has been negligible, however).

KVB/Analect

Preparing to install a continuous emissions-monitoring system, workers drilled ■ 20-cm port in a concrete smokestack at a generating station in Jersey City, N.J., in October of 1993.

To date, two auctions have been held. In the one held in March 1993, prices varied considerably, with first-phase allowances going for $131 to $450, and second-phase credits fetching $122 to $310. More recently, allowance prices have more or less stabilized at about $160 for an allowance usable during either phase, and $150 for an allowance usable during the second phase only.

In the other auction, held last March 29, most—120 000—of the allowances were purchased for $18 million by an organization calling itself the Allowance Holding Corp. The company was later traced back to Hunton & Williams, a Richmond, Va., law firm, which is believed to have bought them on behalf of one or more midwestern utilities.

Such anonymity is becoming more common as utilities feel more intense competitive pressures. "The price a utility pays for allowances could convey its marginal costs for compliance over time" with the Clean Air act, explained Michael Gildea, a regulatory analyst with the Edison Electric Institute, the Washington, D.C., trade association representing investor-owned utilities. "This, in turn, conveys part of its internal costs. When ■ utility is in a competitive situation, and conveys this information, it puts itself at a competitive disadvantage."

What *is* in their interests, all agree, is ■ robust and active market, of the sort that still eludes traders. Why this is so is not easy to explain. After all, noted Cantor Fitzgerald's Bartels, "we are dealing with what, by definition, should be considered an ideal commodity. Within ■ vintage, each allowance is perfectly fungible with all others. There's no delivery problem, because they all exist in a database at the EPA. There are no grading problems. And you have major differences in the value of emissions among users. All that should add to and create ■ very nice market, with active buyers and sellers."

Theories about what is holding the market back abound. For one, when trading began a few years ago, it was a practice well outside the realm of most utilities' expertise. "These instruments are unique—entirely different from power or fuel markets," said Michael Hyrnick, manager of the fuel supply department at Ohio Edison Co. in Akron.

PROBLEMATIC PRICING. But "the main reason the allowance market has not flourished is the low price" of allowances, said Lisa Chalstrom, chief of the research, economics, and finance section of the Iowa Utilities Board in Des Moines. "Since utilities can bank allowances for phase 2 compliance, they have no incentive to sell allowances at ■ price below their phase 2 compliance costs per ton of SO_2 removed." She estimated these costs could exceed $200.

"The real question is why the price is so low," she continued. The reason, in her view, is "a glut of allowances on the market that were created by the [Clean Air Act] amendments. For political reasons, special allocations of allowances were made" to generators fitting a diverse variety of categories—those with certain capacity factors or emission rates, or in certain states, or owned by utilities investing in efficiency and conservation, and so on. "This influx of unearned allowances on the market lowers the value of earned allowances and lessens the incentive for units to overcontrol" and thereby "earn" allowances, Chalstrom asserted.

The market is also said to be still feeling the effect of high estimates of allowance prices, which before trading actually began were predicted to be around $1000. On the basis of these values, some utilities affected by the first phase chose to follow relatively high-cost compliance options, such as installing scrubbers. Many of these utilities are now reluctant to sell any of their excess allowances at ■ steep loss, preferring in-

stead to bank them for use in the future.

The climate created by developments of this nature was not exactly conducive to wheeling and dealing. "Some segments of the industry, until recently, viewed the market perversely," said Bartels. "The talk a year ago was, how much lower must the cost of allowances be *below* my other compliance options before I will consider them. That's absolutely wrong on an economic basis, because allowances are so much more flexible. If you build a scrubber, you've got a scrubber for 30 years [and] a coal contract might be for five, 10 years, whereas allowances have an option value—you can make a profit if the price goes up. Industry should be willing to pay a premium for allowances."

REGULATORY MISGIVINGS. As with any new administrative or financial practice in the utility industry, state regulators are also a powerful force. So far, they have retarded matters, in Bohi's opinion. "No state has been pro-active in encouraging trading of allowances," he said in an interview. "Certainly, no state has worried about leveling the playing field by making sure cost-recovery rules are not biased, one way or another, against trading allowances."

The Iowa Utility Board's Chalstrom disputed this assertion, noting that her organization specifically reformulated its accounting and rate-making rules to eliminate fiscal bias against allowances. The latter rules were changed to allow utilities to recover the costs of allowances needed for compliance right away, in much the same way that they can recover increased fuel costs—without waiting for a rate case.

The biggest problem, in Bohi's view, are the big coal-producing states, which are not surprisingly trying to protect their industries. In order to ensure that their utilities will keep burning local—and often highly sulfurous—coal, several have adopted regulations that clearly favor the installation of scrubbers. In West Virginia, for example, a utility that installed a scrubber was allowed to recover costs right away, rather than going through the usual utility procedure: borrowing the necessary funds and investing them in pollution-control equipment, and then applying to the public utilities commission for authorization to recover the investment and a reasonable return on it through higher customer charges after the equipment has been placed in service. The procedure is intended to protect ratepayers through the use of "post-construction prudency" and "used and useful" determinations to determine the funds were wisely spent.

In Illinois, utilities are in effect barred from reducing their use of in-state coal without a special review by and permission from the state's Commerce Commission. (The legislation was found unconstitutional by a U.S. district court.) The state has also demanded that scrubbers be installed at two generating stations, but imposed no deadline. So Illinois Power Co.'s Baldwin plant and Commonwealth Edison's Kincaid do not yet have the scrubbers in place. In fact, Illinois Power is "about the only utility that has used allowances aggressively to come into compliance in phase 1," Bohi said.

The danger of such enthusiasm for scrubbers is that it could eventually increase the price of electricity, if it has not done so already. Installation and maintenance of scrubbers on a relatively modern plant averages about $300–$400 per ton of SO_2 removed—but the costs can be as high as $800 per ton, according to estimates by Carolina Power & Light and other utilities. Allowances, on the other hand, are now trading for about $160.

"In theory, utilities should not be incurring costs above the allowance prices; however, the costs are running up to six times the allowance prices," said Kenneth Rose, senior economist at the National Regulatory Research Institute. "Sooner or later, regulators are going to catch on to this and the utilities with these high costs will be facing some rather large disallowances or be uncompetitive compared to utilities with lower costs."

Bohi, however, blames the problem on regulators. "It appears that regulators are not encouraging their utilities to do the right thing," he said. "By the right thing, I mean the cheapest thing for the ratepayers."

Even when allowances are used to financial advantage, however, regulations are generally structured so that any income generated by the trading is returned to ratepayers, leaving utilities with little incentive to trade. In Indiana, another state strongly promoting the use of scrubbers, a deal between the state's Utility Regulatory Commission and Southern Indiana Gas & Electric Co. requires the utility to credit to ratepayers almost all revenues from the sale of allowances. The single exception involves a special pool of 79 500 credits earned by installing scrubbers at the utility's F. B. Culley plant. If the utility can sell these allowances for more than $365—about $200 more than the going price—it is permitted to keep the difference. If it sells them for less than $365, however, the utility's shareholders must make up the difference. "To my mind, it's basically a scheme that discourages trading," said Bohi.

"Regulators have got to allow utilities to profit from the purchase or sale of allowances," Bohi added. "Utilities must be allowed to share with ratepayers [in] the benefits of trading, rather than passing them all along to the ratepayers."

It is not clear, however, that all utilities are interested in such sharing. In Iowa, according to Chalstrom, the utilities board and an organization representing ratepayers tried to implement a scheme whereby allowance profits would be divided among utility shareholders and ratepayers, but only one utility—Midwest Power in Des Moines—was interested. The others were scared off by provisions that would have required shareholders to bear part of any losses as well.

Coal-producing states, it might be added, are not alone in obstructing trading, intentionally or otherwise. In March 1993, the New York State attorney general and environmental commissioner sued the EPA, alleging that the EPA's acid rain plan in general—and the allowance-trading provisions in particular—would further damage the state's air quality and natural resources. The suit foresaw midwestern utilities buying allowances to let them keep on emitting pollutants that drift into New York. The state's legislature has also been considering legislation to restrict allowance trading.

Bartels calls the New York action "foolish. New York State is a big beneficiary of this program," he asserted. "The midwest is going to be where much of the cleanup takes place."

To some observers, manifestations of regulatory hostility point to the real and underlying problem: since allowance trading is still fairly new, regulators have not yet compiled much of a track record on how they regard the practice. Utilities are generally run in a conservative manner and are therefore hesitant to plunge right into it, these observers say. "What I hear is, they're concerned about allowance transactions because of uncertainty about how they will be viewed by the regulators," said EPRI's Niemeyer. Although such trepidation does indeed seem widespread in the industry, no specific instances of regulatory second-guessing with regard to allowance trading have yet come to light.

Bartels, for one, believes that much of the concern regarding regulatory uncertainty is exaggerated. "Utilities must realize they will never get regulatory certainty," he said. "It's not part of the system in which they do business. They buy and sell energy all the time, and sometimes they suffer a disallowance. But in the end, the smartest business decision is always the most defensible. Utilities know that—they've had decades of experience with energy transactions."

TO PROBE FURTHER. The March 1994 edition of *The Electricity Journal* had a three-part report titled "Fumbling on Emissions Trading?" The journal's offices are at 1932 First Ave., Suite 809, Seattle, WA 98101-1040; telephone 206-448-4078.

The National Regulatory Research Institute, the research arm of the National Association of Regulatory Utility Commissioners, has published five reports on allowance trading. The most recent one, "Regulatory Treatment of Electric Utility Clean Air Act Compliance Strategies, Costs, and Emission Allowances," is dated December 1993. For a copy, call the Institute's publications office at 614-292-5425.

Many of the allowance brokers have promotional pamphlets detailing how their systems work. Cantor Fitzgerald, for example, has one on its Environmental Brokerage Services; it is available by writing to Cantor Fitzgerald Brokerage L.P., Environmental Brokerage Services, One World Trade Center, 105th Floor, New York, NY 10048; 212-938-4250; fax, 212-938-4252.

The IEEE Field Awards

For work on topics ranging from hot-carrier effects in MOS devices to the design of high-speed power generators, 23 engineers are honored

The IEEE's Board of Directors has conferred the 1994 Technical Field Awards on 23 individuals who have made outstanding contributions to various areas of electrical and electronics engineering. The awards and those who received them are listed below.

• The Cledo Brunetti Award to **Eiji Takeda** (SM) "for pioneering contributions to the characterization and understanding of hot-carrier effects in MOS devices."

Takeda is department manager of the ULSI Research Center in Hitachi Ltd.'s Tokyo-based Central Research Laboratory. In the course of his work on very large-scale integrated (VLSI) device physics, process technologies, and memory applications, he has created new and highly reliable submicrometer MOSFET structures. Besides developing in 1983 the first universal description of device parameters degraded by hot carriers, he proposed the first physical model of device degradation resulting from hot-carrier injection. Takeda's current interests include thin-film silicon-on-insulator devices, flash memory, and nanometer lithography.

He has published more than 120 international technical papers, as well as two books on hot-carrier effects, and was a guest editor of *IEEE Transactions*' special issue on reliability, in December 1988.

• The Control Systems Award to **Elmer G. Gilbert** (F) "for pioneering and innovative contributions to linear state space theory and its applications, especially realization and decoupling, as well as to control algorithms."

Gilbert joined the department of aerospace engineering at the University of Michigan, Ann Arbor, in 1957 and became a full professor in 1963. At present, he holds appointments in that department and in the university's department of electrical engineering and computer science.

During the 1950s and 1960s, Gilbert developed and applied analog and hybrid computers. His 1963 paper on controllability and observability in multivariable linear systems is well known for its original contributions to canonical structure and minimal realizations. In 1969 he published a complete solution of the linear, state-feedback decoupling problem. In recent years, Gilbert has focused on nonlinear systems, robotic path planning in the presence of obstacles, and the feedback control of linear systems with pointwise-in-time constraints on state and control. Gilbert holds eight patents on various computer devices.

• The Herman Halperin Electric Transmission and Distribution Award to **Abdel-Aziz A. Fouad** (F) "for contributions to electrical power system analysis leading to improved control and stability of large utility systems."

Fouad, a professor in the electrical engineering and computer engineering department at Iowa State University, Ames, joined its faculty in 1960. Power system dynamics and control has been the focus of his research. His recent work includes dynamic security assessment, the use of the transient-energy–function method in the stability analysis of large power systems, and the analysis of stressed interconnected power networks. Fouad has also written 90 journal articles and two books.

Last year he was awarded the IEEE Power Engineering Society's Outstanding Power Engineering Educator Award.

• The Masaru Ibuka Consumer Electronics Award to **Carl G. Eilers** (F) "for pioneering contributions to FM stereophonic and television multichannel sound broadcasting systems."

Eilers, manager of electronic systems research and development for Zenith Electronics Corp., Glenview, Ill., joined the company in 1948 as an engineer working on subscription TV scrambling. As manager of what became Zenith's circuits and communications research group, he led its development of stereo FM broadcasting—work that led to a U.S. national and international standard. At present, he is working on high-definition TV. He's the author of more than 25 papers and been granted 17 patents.

• The Award in International Communication to **Stephen Temple** (nonmember) "for contributions to the development and furtherance of worldwide telecommunications standards."

Temple's award comes in part for his efforts at the United Kingdom's Ministry of Posts and Telecommunications, which he joined as a satellite systems engineer in 1971. Until 1979, he represented the ministry at meetings of the International Radio Consultative Committee of the International Telecommunication Union.

Temple moved to the telecommunications division of the Department of Trade and Industry in 1984 as director of technical affairs. He was instrumental in helping to set the technical underpinnings, agreed to at this point by 70 operators in 45 countries, of the European Global System for Mobile Communications' (GSM's) digital cellular radio system. He has also been influential in opening the 18-GHz region of the spectrum to personal communications services.

In 1987, he worked with others to reform European telecommunications standards making, which led to the establishment of the European Telecommunications Standards Institute. Since 1992, Temple has been responsible for the telecommunications, radio, and broadcasting industries in the UK.

• The Reynold B. Johnson Information Storage Award to **C. Denis Mee** (F) "for contributions to the design of optical, magneto-optical, and magnetic recording files."

Mee, an IBM Fellow Emeritus, emigrated from Britain to the United States to join CBS Laboratories, where he developed a magnetic recording system for a high-density magnetic-tape audio stereo recorder in 1959. Upon joining IBM Corp. in 1962 as manager of the magnetic devices group at the Thomas J. Watson Research Center, he developed technologies for such applications as multilayer magnetic thin-film devices.

Mee transferred to the Advanced Technology Project, San Jose, Calif., three years later and initiated projects in magneto-optical recording, holographic storage, and magnetic bubbles. In 1970 he became leader of a wide-ranging magnetic-recording technology project, which laid the foundation for the thin-film heads and disks that appeared in tape storage products during the 1980s; he holds some of the earliest patents on thin-film heads and magneto-optical recording methods.

In 1981, Mee started a new laboratory for advanced magnetic recording. Six years later he started a similar operation for optical data storage. Both labs have developed new components currently used in storage products.

• The Richard Harold Kaufmann Award to **Daniel J. Love** (LF) "for the development and application of unique analytical techniques to improve phase and ground fault protection of industrial power systems."

Love, now associated with LCR Consulting Engineering, a firm specializing in electro-

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forensic engineering, joined Bechtel in 1968 after working as a test engineer in a steel mill and designing generating stations. At Bechtel, his assignments included designing industrial plants and generating stations and developing plans for protecting them and distribution systems, as well.

For 480-V systems, Love created inverse damage limit curves, which are used to coordinate ground fault protection. He also published more than 30 technical papers on protection and other subjects.

• The Koji Kobayashi Computers and Communications Award to **Jonathan S. Turner** (F) "for fundamental contributions to communications and computing through architectural innovations in high-speed packet networks."

Turner joined the faculty of Washington University, St. Louis, in 1983, following a stint at Bell Laboratories, Napier, Ill. (1977–83), where he developed diagnostics software for telephone switching systems and was the lead system architect for Bell Labs' first applied research project on fast packet switching. He became a full professor in 1990.

The design and analysis of switching systems, particularly ones that are able to support multipoint communication, are Turner's primary research interest. He holds 17 patents and has many widely cited publications to his credit. His broadcast packet-switch architecture was among the first asynchronous transfer mode (ATM) switch architectures to address effectively the problem of multipoint communication.

• The Morris E. Leeds Award to **Oliver C. Wells** (nonmember) "for contributions to the application of scanning electron microscopy in dimensional, electrical, and magnetic measurements."

Wells, a member of the Cambridge University team that developed the scanning electron microscope (SEM), was later employed (1959–64) at the Westinghouse Research and Development Center in Pittsburgh, where he was the first to obtain an induced signal image from a semiconductor device and to demonstrate SEM-type registration during the electron beam fabrication of semiconductor devices.

In 1966 he joined IBM's Thomas J. Watson Research Center, where he is now a researcher emeritus, and began full-time investigations into SEM theory and applications. With others, he discovered the low-loss electron image in the SEM; the reflection SEM image for a solid sample in the high-field region of a condenser-objective lens; and several new ways of studying magnetic samples in the SEM.

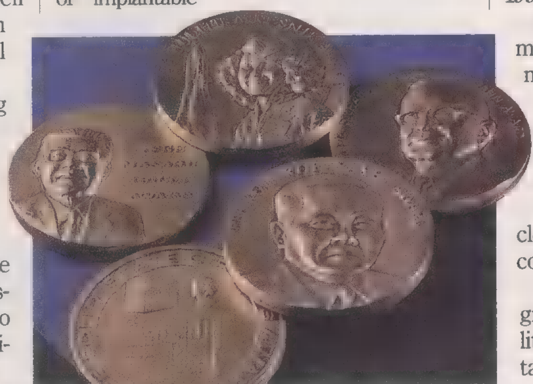
• The Morris N. Liebmann Memorial Award to **Lubomyr T. Romankiw** (M) "for innovations in thin-film fabrication processes to realize inductive and magnetoresistive thin-film heads for large-scale storage."

Romankiw joined IBM Corp.'s Thomas J. Watson Research Center, where he is now senior manager of the Electrochemical Technology Department (Manufacturing Research) and IBM Fellow, in 1962. Since then, he has developed fabrication processes for electronic components and devices using a combination of vacuum, lithography, and electrochemical techniques.

His most important contribution, affecting magnetic storage, was the development of the fabrication technology for inductive–read-write heads and integrated inductive-write magnetoresistive-read thin-film heads. At present, he and his co-workers are pioneering the high-speed electrochemical micromachining of minute electronic components, as well as high–energy-density batteries.

The holder of 43 patents, Romankiw has 110 inventions to his credit and is the author of more than 100 scientific papers.

• The Eli Lilly Award in Medical and Biological Engineering to **Earl E. Bakken** (F) "for pioneering development and commercialization of implantable cardiac pacemakers."


Andy Schenck

Bakken founded Medtronic Inc. in 1949 to repair electronic appliances for hospitals, clinics, and doctors' offices in his native Twin Cities. In 1957, a major power failure occurred there, prompting a request by Dr. C. Walton Lillehei, an open-heart-surgery pioneer, for a battery-powered cardiac pacemaker.

Bakken constructed the first such device that same year, and in 1960 Medtronic began to produce the first reliable battery-powered, implantable pacemaker, soon becoming the foremost producer of implantable bradycardia pacing systems. He retired as a corporate officer in 1989 but continues to serve as director and consultant to Medtronic, which continues to develop and manufacture therapeutic medical devices.

His many awards include an IEEE Centennial Medal.

• The Jack A. Morton Award to **Robert E. Kerwin** (PM), **Donald L. Klein** (nonmember), and **John C. Sarace** (nonmember) "for pioneering work and the basic patent on the self-aligned silicon-gate process, a key element in the fabrication of very large-scale integrated circuits."

At Bell Laboratories in the mid-1960s, Kerwin, Klein, and Sarace labored to improve the performance of MOS devices and to fabricate them in ways that would increase their stability and density. This research led to the use of doped polysilicon films as electrodes and conducting interconnects—a major breakthrough that made possible today's high-density, high-speed integrated circuits.

Kerwin, general manager of AT&T Corp.'s Intellectual Property Division, joined Bell Labs in 1964, following several years as a member of the Polymer Research Group at the Mellon Institute. He became supervisor of Bell Labs' Lithographic Development Group in 1970 and a decade later took engineering responsibility for the Integrated Circuit Design Capability Line, focusing on the development of CMOS devices.

Ten years later Kerwin was appointed head of the Component Quality and Reliability Department of Bell Labs' Quality Assurance Center. He transferred to AT&T corporate in 1986 and assumed his present position in 1990.

Klein, a consultant on microelectronic materials and processes who retired as senior engineer for IBM Corp. in 1987, started at Sylvania's Physics and Chemistry Laboratory in 1952. Six years later he joined Bell Labs, where he was inventor or co-inventor on patents relating to semiconductor contacts, atomically clean surfaces, tunnel diodes, and polysilicon-gate self-aligned FETs.

In 1967 he moved to IBM, forming a group that addressed semiconductor lithography. Later, he studied silicon crystal growth, ion implantation technology, and electronic packaging technology.

Sarace, who retired as Rockwell International Corp.'s technical director for fabricating infrared devices used in military surveillance applications, worked at Bell Labs from 1962 to 1967. In 1968, he became section head of materials development at Harris Semiconductor Inc. and directed research into dielectric isolation techniques for radiation-hard bipolar devices.

Two years later, he joined the David Sarnoff Research Center and focused on silicon-on-sapphire CMOS process development and device performance. Sarace moved to Rockwell in 1974 as section head of the company's Microelectronics Research and Development Center. He assumed his final position at Rockwell in 1987.

• The Frederik Philips Award to **Minoru Nagata** (F) "for leadership in research and development of silicon integrated circuits and fostering international information exchange."

Nagata joined Hitachi Ltd.'s Central Research Laboratory (CRL) in 1956. From 1964 to 1965 he was a research associate at Stanford Electronics Laboratory in California, helping to set up the Stanford IC Laboratory. Returning to Hitachi CRL in 1965, he worked on linear ICs and (from 1968 to 1972) supervised a group researching MOS large-scale integration (LSI) and

computer-aided design (CAD) for ICs. In 1972 Nagata was named department head of CRL's Integrated Circuit Laboratory. Since 1985, he has been director and senior chief scientist, corporate technology.

Important projects Nagata initiated include research into short-channel and high-speed n-MOSFETs, n-channel dynamic-RAM technology with low-voltage operation, an integrated MOS-LSI layout program with a unit cell concept, and a two-dimensional device simulation program.

• The Emanuel R. Piore Award to **John L. Hennessy** "for contributions to quantitative evaluation of computer architectures and the successful implementation of reduced instruction-set computer (RISC) architecture."

At Stanford University, California, since 1977, Hennessy is the Willard and Inez Kerr Bell endowed professor of electrical engineering and computer science. In 1981 he initiated one of three early RISC research prototypes. In 1984–85, he helped found MIPS Computer Systems Inc., which developed microprocessors based on this concept.

His research interest is the architecture and design of scalable multiprocessors, as well as the software needed to exploit such machines. With David Patterson, he is the author of *Computer Architecture: A Quantitative Approach* (1990), which is now regarded as a standard text, and of *Computer Organization and Design: The Hardware/Software Interface* (1993).

• The Judith A. Resnik Award to **Johannes Dietrich** (nonmember) "for development of a successful high-performance, rugged, multisensor miniaturized robotic gripper for use in the outer space environment."

Dietrich has been employed by the German Aerospace Research Establishment (DLR) since 1981. For five years, he developed robot sensory and actuator systems, especially miniature laser triangulation range finders, both strain-gauge–based and compliant force-torque sensors, tactile arrays, and low-friction drives.

From 1986 to 1992 he was chief developer of the multisensory robot gripper for the Rotex space robot. His team created a lightweight, high-force gripper that worked perfectly on shuttle flight STS 55, in April 1993. Since 1993 he has been chief engineer and research project leader for mechatronics research in DLR's space robot program.

• The David Sarnoff Award to **Won T. Tsang** (F) "for innovative contributions to the design of novel quantum well semiconductor lasers and to epitaxial growth processes."

Tsang joined Bell Laboratories' Solid State Electronics Research Laboratory, Murray Hill, N.J., in 1976, to study semiconductor lasers. In 1984 he became head of the electrophotonics research department of Bell Labs' Holmdel facility, and since 1987 has headed the semiconductor electronics research department at Murray Hill. His responsibilities include managing semiconductor laser research, particularly high-performance InP/InGaAsP lasers for light-wave communications. He also conducts his own research on semiconductor lasers and other devices grown by chemical beam epitaxy.

In the field of semiconductor laser structures, Tsang's work has had a major impact. He was the first to demonstrate low-threshold lasers grown by molecular beam epitaxy (MBE) and also achieved the first current injection of multiquantum-well lasers—breakthroughs that are still used in a high proportion of the compact-disc lasers produced today.

In 1983 he and his colleagues demonstrated a tunable laser formed from two independently controllable current injections using two optically coupled cavities. This led to today's basic laser tuning mechanism. More recently, Tsang extended the solid-source molecular beam epitaxy technique of crystal growth to metal-organic sources to grow device-quality InP/InGaAs epitaxial layers—a method now widely used to fabricate photonic and electric devices.

• The Solid-State Circuits Award to **Paul R. Gray** (F) "for contributions to analog integrated circuit design, especially for MOS switched capacitor circuits."

Gray spent several years at Fairchild Semiconductor's R&D Laboratory until 1971, when he joined the department of electrical engineering and computer sciences at the University of California, Berkeley, where he is now a professor. During leaves of absence from the university, he served as project manager for telecommunications filters at Intel Corp. (1977–78) and as director of CMOS design engineering at Microlinear Corp. (1984–85).

His research interests have included bipolar and MOS circuit design, electrothermal interactions in ICs, device modeling, telecommunications circuits, and analog-digital interfaces in VLSI systems. Gray and his colleagues contributed new circuit techniques allowing MOS VLSI to be used for such analog and mixed-signal functions as continuous and sampled data filters and analog-digital converters. With R.G. Meyer, he authored a widely used college textbook on the design of analog ICs.

• The Charles Proteus Steinmetz Award to **Clayton H. Griffin** (LF) "for leadership and continuing contributions to the development of protective relaying standards."

Griffin, who retired from Georgia Power Co. as manager of system protection and control, joined the company in 1949 as a tester in the system operations department. His department was responsible for all relay application, field test, and control computer engineering on the Georgia Power system.

In 1966, Griffin joined the IEEE Power System Relay Committee (PSRC), where he has helped develop more than a dozen IEEE standards, including guides for protecting generators, power transformers, shunt reactors, and pumped storage hydro plants. In 1983 Griffin formed the IEEE Standards Coordinating Committee on Dispersed Storage and Generation, which has produced four IEEE standards, including the basic document for this technology.

• The Nikola Tesla Award to **Carl Flick** (LF) "for long-term creative contributions and leadership in the design and development of advanced high-speed generators."

Flick, a consultant for Techno-Lexic, retired from Westinghouse Electric Corp. in 1989 as an advisory engineer. He had joined the company in 1952 as an assistant engineer designing turbine generators. Flick's career focused on high-speed round-rotor machine design. His early research involved the design and application of machines to electric utilities and industrial power plants.

Soon he went to work on unusual products with complex performance requirements, specializing in designs for low and closely controlled reactance coefficients—for example, a very-large–pulse power generator that delivered short-circuit currents comparable to those generated by a normal power system. Low reactance was also required for superconducting generators. He led a team in this challenging effort, which yielded most of his six patents and 20 technical papers.

• The Graduate Teaching Award to **Thomas K. Gaylord** (F) "for contributions to graduate education in optics and electrical engineering and for inspirational guidance of Ph.D. students."

Gaylord, Julius Brown chair and Regents' professor of electrical engineering at the Georgia Institute of Technology, in Atlanta, became an assistant professor there in 1972. Over the years, he helped establish a program of courses and research in optics.

In his own research Gaylord has participated in the development of rigorous coupled-wave analysis, an exact electromagnetic method of characterizing grating diffraction that is now used throughout the world to analyze and design diffractive optical components. He has also helped develop a new type of semiconductor electronic and optoelectronic device based on quantum-mechanical electron-wave propagation effects. Gaylord also holds eight patents and has written some 180 technical journal publications.

• The Undergraduate Teaching Award to **N. Narayana Rao** (F) "for inspirational teaching of undergraduate students and the development of innovative instructional materials for teaching courses in electromagnetics."

Rao joined what is now the department of electrical and computer engineering of the University of Illinois at Urbana–Champaign, where he is currently a professor and associate department head, in 1965. He has carried out research in the general area of ionospheric propagation, taught a wide variety of courses, and developed new courses in electromagnetic fields and radio wave propagation. He is also the author of textbooks—*Basic Electromagnetics With Applications* (1972) and the four editions of *Elements of Engineering Electromagnetics* (1977, 1987, 1991, and 1994)—and of innovative instructional software.

M. Vidyasagar

A former prodigy and professor, this pacifist who loves poetry has taken charge of a defense research center in his native India

Mathukumalli Vidyasagar is opinionated yet witty, forthright yet friendly. There's a touch of silver in his hair and beard, and he appears at ease in an open-necked shirt, cotton trousers, and sandals. He likes to sing and loves poetry, which he reads whenever he has even a few moments to spare. In a round of free associations, he probably would not be what sprang to mind when the prompt was "defense department official"—which is, technically, what he is.

"I'm not a very unusual person," he insists, but evidence to the contrary abounds.

For one thing, there was his response to the mid-life question, what do you do after earning a bachelor's degree at age 17, a Ph.D. at 21, and a full professorship at Sir George Williams (now Concordia) University in Montreal at 29, not to mention an IEEE fellowship citation (for "contributions in the stability analysis of linear and nonlinear distributed systems") at 35?

What he did, at age 41, was pack up and move with his wife and six-year-old daughter to Bangalore, India, to direct the recently established Centre for Artificial Intelligence Research, under the Indian Defence Research and Development Organization. The pay in his new job, though excellent by Indian standards, was still less than a twentieth of what he had been earning in Canada. He had not lived in India for decades—his parents, his sister, and he had left almost 30 years before, and it had been 17 years since his wife had left the country to marry him.

His daughter missed their comfortable, four-bedroom, yellow split-level home on the edge of the University of Waterloo's pastoral campus, where Vidyasagar had a tenured professorship and an office a short walk from his house. "Many of my friends were surprised when I took this job at the defense ministry," he said, "because I am basically a pacifist."

MENTAL OVERDRIVE. To understand such complexities requires a little history. Vidyasagar is a kind of intellectually restless prodigy who has changed his area or place of research every few years.

Glenn Zorpette Senior Associate Editor

"I've never met anyone whose mind works faster," said Bruce A. Francis, who was advised by Vidyasagar for a year during a Ph.D. project and is now a professor at the University of Toronto. "You don't even have to finish sentences, and he knows what you're going to say. He absorbs entire fields in what seems a few weeks."

Indeed, in 1960, Vidyasagar's entrance into the public school system in Columbia, Mo., caused a minor commotion as school officials tried to determine what grade to place him in. "First of all, they refused to believe a 13-year-old belonged in grade 12," said Vidyasagar (whose name, translated from the Telugu, means "ocean of knowledge"). "They wanted to put me in grade 7."

The family was only in Columbia because the father had accepted a position at the University of Missouri, and he was adamant. After looking at the boy's school books, the principal, too, inclined to moving him ahead.

On his second or third day in math class, the white-haired teacher, Miss Nellie Kitchen, put a problem on the board. "Suppose A, B, and C are any three numbers," Vidyasagar recalls her saying. "Show that the log to the base B of A times the log to the base C of B times the log to the base A of C equals 1." Her challenge was met with mostly blank stares.

"I was very shy," Vidyasagar recalled. "I was literally just off the plane, this little fellow with a thick accent from a strange land. After a few minutes, I told her how to do the problem. She said, 'Oh, of course, your father is a professor of mathematics.' I said, 'Well, actually, we did this problem in India last year [in the 11th grade].' Suddenly, my classmates realized the standard in India wasn't so bad after all."

LONELY GENIUS. But his acceptance was strictly academic. "It was very lonely. In India, your whole social life doesn't revolve around school. I studied with one bunch of people [three or four years older] and played with kids my age. In the states, I found almost no social life outside of school. I didn't know a single person my own age."

Happily, the solitude lasted only a year. Just shy of his 14th birthday, he started at the University of Missouri, which was much more to his liking. After his father's next move, though, to Alberta, Canada, he transferred to the University of Wisconsin in Madison, where he got his bachelor's, master's, and Ph.D., all in electrical engineering.

At Wisconsin, the teenager could indulge his other passion, for poetry in Telugu, the tongue of Andhra Pradesh in South India, where he was born. "They had a really good Oriental language program, with thousands of Telugu books. Mostly trash. They had gotten some money to buy books, and 80 percent of them were pulp fiction. The other 20 percent were poetry. It was the oddest mix imaginable. I probably read every Telugu poetry book they had."

After getting his Ph.D. in 1969, he taught for a year at Marquette University, in Milwaukee, which he also liked. Nonetheless, those first few years after receiving his Ph.D., when he was teaching undergraduates, were awkward at times for the sociable and athletic young adult. "I mean, I was teaching them in the morning and playing touch football with them in the afternoon," he recalled. "It just didn't work out. I found I couldn't be a professor and hang out with students."

To be closer to his family, he began looking for a more permanent position in Canada. When he found one, in 1970 at Sir George Williams University in Montreal, he was actually farther away from his clan, then based in Alberta. Some families, however, have the ability to be close-knit regardless of where their members are, and Vidyasagar's is one of them.

His peripatetic father went on sabbatical in Madras, and this was to have a profound effect on his son's life. In Madras, one of his mother's friends mentioned that he had a young cousin who might be willing to meet the up-and-coming young professor. And so it was arranged. Or, rather, "introduced."

"It was an 'introduced' marriage," he amplifies for the benefit of a crass Westerner. "'Arranged' is a misnomer. It makes it seem like something where there is no choice—as though someone dictates to you, 'This is the person you are going to marry.' Your parents act like a screening committee. You meet this person, you sit and talk, and then you take the plunge, or don't, as the case may be."

STOLEN GLANCES. He still remembers the details of his first meeting with Valluri Shakunthala, his future wife, on Aug. 19, 1972. "These are awkward situations," he said. "You try to steal glances without making it obvious. What makes it work is that the young people bring a lot of commitment to making it work." Three weeks later, they were married in Madras.

At the time Vidyasagar, no slouch in the peripateticism department himself, was at the University of California, and his new bride's initiation into the United States was an eventful one. "I had to tell her, Los Angeles is a very dangerous place. Once,

Gerry Gropp/Sipa Press (photos)

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Vital statistics:

Name: Mathukumalli Vidyasagar ("Sagar" to his friends)
Date of birth: Sept. 29, 1947
Height: 183 cm **Mass:** 85 kg
Birthplace: Guntur, Andhra Pradesh (north of Madras)
Family: wife, Valluri Shakunthala; daughter, Aparna, 11
Favorite writers: Potana (15th-century Indian poet), Jane Austen, Charles Dickens ("Strangely enough, I don't like English poets, or Telugu prose writers")
Latest (Western) book read: *Genius,* by James Gleick
Languages spoken: Telugu, Hindi, Tamil, English, French, Japanese
Favorite quotation: *karmanyevaadhikaarasthe maa phaleshu kadaachana*—Sanskrit, from the Bhagavad Gita: "Only carrying out your duty is within your power; do not ask for reward"
Fellowships: IEEE, Indian Academy of Sciences, Indian National Science Academy, Indian National Academy of Engineering
Hobbies: golf, jogging, reading poetry, listening to Indian and Western classical music, learning languages
Favorite composers: Thyagaraja (late 18th-century Indian composer), Mozart
Food most missed in India: pesto sauce

when we were out grocery shopping, I said, 'Wait here; I'll go get the car.' I came back, and she said, 'I met this very nice man.' I said, 'What nice man?' She said he had told her, 'You are very pretty, why don't you come with me...' I had to tell her, he wasn't a very nice man."

In the meantime, Vidyasagar was establishing a name for himself as an expert in nonlinear feedback systems, an important research area in control theory. In this endeavor he was fortunate to have the help of Charles A. Desoer, now an emeritus professor at the University of California, Berkeley, and one of the most repected figures in the field. Desoer invited Vidyasagar to spend the summer of 1973 at Berkeley, where the two of them collaborated on a book, called *Feedback Systems: Input-Output Properties,* soon to become the standard reference on the subject.

CAUSING A STIR. A second and more comprehensive textbook, titled *Nonlinear Systems Analysis,* followed; written by Vidyasagar alone, its second edition was released in 1993 by Prentice Hall in Englewood Cliffs, N.J. "I take an area, try to teach it, and then write a book," Vidyasagar explained. "This way, I can understand it for myself."

Having collaborated with the top researcher and written the classic book by age 30, he moved on. In the early 1980s Vidyasagar began focusing on multivariable control, essential in the design of airplanes, robots, and similar high-performance systems. He did early work on a ground-breaking technique, H_∞ optimization, for working on multivariable controllers in the frequency domain, and he invented an analogous, time-domain technique called L_1 optimization. Then came another book—the first to describe H_∞ optimization—on multivariable control, and, again, it was time to move on.

But he did not go quietly. A plenary talk he gave at the 1985 IEEE Conference on Decision and Control caused such a stir that after he finished speaking, "many people actually jumped up, they were so angry," Francis recalled. "He felt we were working on the wrong kinds of problems, and things were getting stale. So he gave some examples of important control problems that we should be working on." Among Vidyasagar's picks were hybrid systems, which in control engineering means systems that combine logic or symbolic elements with more traditional analog or digital electronics.

Nine years later, Vidyasagar has been largely vindicated, in Francis's view: "He got people upset then, but he was right, in a lot of aspects." Hybrid systems, for example, have attracted much attention in recent years, to the extent that control conferences today often devote an entire session to them.

In the mid-1980s, he began working in robotics, coauthoring a paper on the robust control of robots. This work led to his current position in Bangalore, which, in turn, has led him into projects in neural networks and artificial intelligence.

He attributes his career pattern of changing fields every few years to the German mathematician David Hilbert (1862–1944), another intellectually restless savant and the subject of a biography he read many years ago. As for the secret of his own books' success, he believes it is mostly a matter of tone. "I'm more interested in educating the reader than impressing the reader. I think I'm a good expositor. Good exposition makes the research [described] seem better than it is."

"Many famous people don't read other people's papers in their field," he added after a few moments' reflection. "They think they don't have anything to learn from other people. That's preposterous, isn't it?"

At 41, Mathukumalli Vidyasagar returned to India out of a desire to do more in life than pursue his own research.

The comment stems from an inner struggle; after all, this is a man who has excelled spectacularly for most of his life but who has deliberately resisted surrendering to arrogance. If this struggle is generally won, it is because of his wife—who, he said, "thinks I have already lost the battle."

"People like me need wives that deflate them occasionally," he concluded.

CANADA'S LOSS. In his current position, he is clearly a very, very big fish in a small pond. The Centre for Artificial Intelligence Research (CAIR) has 30 scientists and an annual budget of 15 million rupees (US $500 000). Research topics include robotics, flight control systems for military jets, neural networks, computer vision, and knowledge-based systems.

Why did he make the move? "Signs of creeping middle age, I guess. I mean, I was 40 years old, and I'd been a professor for 20 years. One can keep doing the same thing, with no sense of suspense anymore. I could have kept doing research at a certain pace for as long as I wanted. But I was interested in doing something different. I didn't want to come back to India as a professor.

"I wanted to know if I could contribute something more than my personal research. What is it a person like me can do for a country? I'm not an industrialist who can start a business and provide jobs. The best I can do is start an enterprise like this, where some good people can get together and do some good research."

Francis, while confirming that nationalism was part of Vidyasagar's motivation, felt there were probably more fundamental reasons as well. "He wanted his daughter to be educated in Indian culture, and with an Indian value system," he said. "He sometimes spoke of the [North American] divorce rate and drug use...the things we all worry about here."

While there were some trying times early on following his return, Vidyasagar said he learned as the months went by either to circumvent or to accept India's peculiarities. "The main difference in India is that there are no procedures or rules that are clearly enunciated," he said. "Everything is extremely *ad hoc.* What we have is chaos masquerading as bureaucracy. That's what it took me a long time to get over."

Even being a military man is something Vidyasagar has become comfortable with. "There's a difference between Indian and U.S. defense officials," he observed. "It stems from the different world views of these countries. India really does not have extraterritorial ambitions...[whereas] U.S. policy is driven by the global police concept." His center does no classified work, and he is only rarely put on a committee dealing with classified matters, he said.

His comfortable, book-lined office at CAIR is fairly typical of a senior control engineering researcher— except for the pile of Telugu poetry books on the desk. "I read it to take a break," he said, almost sheepishly. There's a Sun workstation, a sofa, art on the walls ("a prize-winning painting by my daughter," he explained proudly), and a soothing green view of tropical trees outside the windows.

A love of poetry runs in his family. Once, flipping through *Telugu Poets of the 19th Century,* he came across the name of an ancestor, Mathukumalli Narashimha Sastry. His grandfather, too, loved poetry and he shared the passion with young Vidyasagar.

The family, he added, also has a celebrated poetess (named Mathukumalli Indumathi). His visitor finds this interesting, because with all his accomplishments, this is the only boast Vidyasagar makes during a long day of answering questions, sharing his opinions, and describing his life.

"Many families can claim a famous poet," he explained, "but not many a famous poetess, 100 years ago." ◆

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Calendar

(Continued from p. 14)

Nonlinear Optics: Materials Fundamentals & Applications Topical Meeting (LEOS); July 25–29; Hyatt Regency Waikaloa, Hawaii; S. Evans, IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855 908-562-3896; fax, 908-562-1571.

AUGUST

First International Conference on Electronics and Information Technology (COM); Aug. 3–5; Friendship Hotel, Beijing, Julian Chen, IBM Thomas J. Watson Research Center, Box 218, Yorktown Heights, NY 10598; 914-945-2935; fax, 914-945-2141.

Third International Symposium on High Performance Distributed Computing (C); Aug. 3–5; Westin St. Francis Hotel, San Francisco; Geoffrey C. Fox, NPAC Director, Room 3-228, 111 College Place, Syracuse, NY 13244-4100; 315-443-4741; fax, 315-443-1973; e-mail, gcf@pac.syr.edu.

Fourth Workshop on Computers in Power Electronics (PEL, Montreal Section, et al.); Aug. 7–10; University of Quebec, Trois-Rivières, Canada; Adam Skorek, Department d'Ingénierie, UQTR. C.P. 500, Trois-Rivières, PQ G9A 5H7, Canada; 819-376-5071, ext. 3929; fax, 819-376-5152.

International Symposium on Applications of Ferroelectrics (UFFC); Aug. 7–10; Conference Center, University Park, Pa.; Amar Bhalla, 253 MRL, Penn State University, University Park, PA 16802; 814-865-9232.

Intersociety Energy Conversion Engineering Conference—Iecec '94 (ED); Aug. 7–12; Doubletree Hotel and Conference Center, Monterey, Calif.; Robert C. Winn, 410 Silver Springs Circle, Colorado Springs, CO 80840; phone and fax, 719-548-1601.

International Workshop on Memory Technology Design and Testing (C); Aug. 8–9; Hilton Hotel, San Jose, California; Rochit Rajsuman, Department of Computer Engineering and Science, 521 Crawford Hall, Case Western Reserve University, Cleveland, OH 44106; 216-368-5510; e-mail, rajsuman@alpha.ces.cwru.edu; fax, 216-368-2801.

International Geoscience and Remote Sensing Symposium (GRS); Aug. 8–12; California Institute of Technology, Pasadena; Marguerite Schier, MS 183-501, Jet Propulsion Laboratory, 4800 Oak Grove Dr., Pasadena, CA 91109; 818-354-6492.

Hot Interconnects Symposium—HIS (C); Aug. 11–13; **Hot Chips Symposium** (C); Aug. 14–16; Stanford University, California; R. G. Stewart, Stewart Research Enterprises, 1658 Belvoir Dr., Los Altos, CA 94024; 415-941-6699; fax, 415-941-5048.

Magnetic Recording Conference—TMRC '94 (MAG); Aug. 15–17; University of California, San Diego; Roger F. Hoyt, IBM Almaden Research Center, 650 Harry Rd., K01/803, San Jose, CA 95120-6099; 408-927-2118; fax, 408-927-3204.

Ninth International Symposium on Intelligent Control (CS); Aug. 16–18; Holiday Inn Crowne Plaza, Columbus, Ohio; Umit Ozguner, Department of Electrical Engineering, Ohio State University, 2015 Neil Ave., Columbus, OH 43210; 614-292-5940; fax, 614-292-7596.

Topical Workshop on Heterostructure Microelectronics (ED, MTT); Aug. 17–19; Teijin Fuji Conference Hall, Mount Fuji Resort Area, Japan; Dimitris Pavlidis, University of Michigan, EE&CS Department, 1301 Beal Ave., Ann Arbor, MI 48109-2122; 313-747-1778; fax, 313-747-1781.

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Université du Québec à Montréal

Calendar

tems (CS); Aug. 19–20; Rutgers University, Piscataway, N.J.; Zoran Gajic, E&CE Department, Rutgers University, Piscataway, NJ 08855-0909; 908-932-3415; fax, 908-932-2820.

First International Particle Technology Forum (IM); Aug. 17–19; Denver Marriott, Colorado; Denise DeLuca, American Institute of Chemical Engineers, 345 E. 47th St., New York, NY 10017; 212-705-7344; fax, 212-752-3297.

International Conference on Application Specific Array Processors—ASAP '94 (C); Aug. 22–24; Fairmont Hotel, San Francisco; Earl E. Swartzlander Jr., Department of Electrical and Computer Engineering, University of Texas, Austin, TX 78712-1084; 512-471-5923; e-mail, e.swartzlander@compmail. com; fax, 512-471-5907.

International Conference on Millimeter-wave and Far-Infrared Science and Technology (ED); Aug. 22–26; Xigiao Hills Hotel, Guangzhou, China; Gail Tucker, Georgia Institute of Technology, GTRI/CS, Atlanta, GA 30332; 404-894-3500; fax, 404-894-5875.

International Symposium on EM Compatibility (EMC, Chicago Section); Aug. 22–26; Palmer Hotel, Chicago; H.. Hofmann, 1210 Lawn Meadow Lane, Naperville, IL 60540; 708-979-3627; fax, 708-979-5755.

Tencon '94 (Region 10, Singapore Section, C); Aug. 22–26; Raffles City Convention Centre, Westin Hotels, Singapore; Jonnovan Hong, (65) 773 1141; fax, (65) 773 1142; e-mail, ieeesgp@solomon.technet.sg.

International Conference on Solid-State Devices and Materials—SSDM '94 (ED, Tokyo Section); Aug. 23–26; Pacific Convention Plaza, Yokohama, Japan; SSDM '94, c/o Business Center for Academic Societies Japan, Honkomagome 5-16-9, Bunkyo-ku 113, Japan; (81+3) 5814 5800; fax, (81+3) 5814 5823.

International Conference on Control and Applications (CS); Aug. 24–26; Strathclyde Graduate Business School, Glasgow, Scotland; Michael J. Grimble, Industrial Control Centre, Strathclyde University, Graham Hills Building, 50 George St., Glasgow GI 1QE, Scotland; (44+41) 552 4400, ext. 2378.

Conference on Lasers and Electro-Optics Europe and the Fifth European Quantum Electronics Convention—CLEO Europe/EQEC (LEO); Aug. 28–Sept. 2; RAI Congress Centre, Amsterdam, the Netherlands; Susan Evans, IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855-1331; 908-562-3896; fax, 908-562-1571.

Vehicle Navigation and Information Systems Conference (VT, Tokyo Section); Aug. 31–Sept. 2; Pacific Convention Plaza, Yokohama, Japan; VNIS '94 Secretariat, Ren Associates Inc., 2-12-14 Hamamatsucho, Minato-ku, Tokyo 105, Japan; (81+3) 3433 2543; fax, (81+3) 3433 3904.

SEPTEMBER

International Conference on Microelectronics (ED); Sept. 5–7; Sheraton Hotel, Istanbul, Turkey; M.I. Elmasry, ECE Department, University of Waterloo, Waterloo, ON N2L 3G1, Canada; 519-885-1211, ext. 3753; fax, 519-746-5195.

20th Conference of IEEE Industrial Electronics (IE); Sept. 5–9; University of Bologna, Italy; A.Tonielli, Department of Electronics and Computer System Sciences, Bologna University, Viale Risorgimento 2, 40136 Bologna, Italy; (39+51) 644 3024; fax, (39+51) 644 3073.

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Several openings exist in the areas of expertise listed. Projects include development of a 10Gb/s SONET communications interface/add-drop multiplexer, and a high throughput ATM switch for use in digital video and gigabit networking applications. As part of a team, you will provide technical leadership in the definition, design, fabrication and testing of hybrid circuit and board-level subsystems. Requires an MSEE, or equivalent, and at least 3+ years' industry experience in the design and integration of high speed digital and GHz electronic systems. Expertise in two or more of the following is needed: high speed digital and/or analog circuit design and implementation, high speed interconnects, multichip modules, and board design, implementation, test and characterization. Familiarity with SONET and ATM technologies is a plus. **Dept. SO701-HDE/YA**

Sr. Hardware Design Engineer

Provide expertise in microwave design and materials, high density electrical and optical packaging, and advanced interconnects. In addition, you will act as a resource in electrical, mechanical, and thermal engineering of hybrids, MCM, board, and system integration of gigahertz communication systems and prototypes. Requires an MS or PhD in EE or Physics, or equivalent, and at least 4+ years' experience in microwave components and packaging techniques. Proven performance in design, development and evaluation of packaging for miniaturized microwave components and systems and experience in multichip hybrid packaging approaches and high performance interconnect technologies. Requires familiarity with optical packaging issues and techniques and a working knowledge of chip attach, bonding techniques and metallurgy. **Dept. SO701-SHDE/YA**

Sr. Project Engineers

Openings exist for Project Leaders to architect and implement advanced SONET and ATM multiplexing and switching systems for use in digital video and gigabit networking applications. Responsibilities include system definition and architecture, implementation, system integration and testing. In addition, you will collaborate with technology leaders in government, national laboratories, industry, and universities to prototype new product and service concepts related to high speed information/video creation, transport, distribution, presentation, performance testing and monitoring. Requires a PhD in EE, CEE, or equivalent, and at least 4+ years' experience in computer, datacom, or telecom industries. Expertise in network architectures, local and/or wide area networks and data communications, including underlying theory as well as practical hardware and software implementation aspects, and/or gigabit/sec communications transport and switching. Experience with high speed digital circuit design a plus. Requires familiarity with SONET, ATM and other LAN technologies, excellent systems design capability, and the ability to identify potential products and applications. **Dept. SO701/SPE-YA**

Software/Hardware System Engineer

Integrate gigabit/s SONET and ATM communication systems for use in digital video networking applications. You will provide senior-level expertise in specifying system architecture and in the definition, design and implementation of microprocessor-based controllers for network interfaces and ATM switching systems. Requires an MS in CS, CEE, EE, or equivalent, and at least 3+ years' industry experience in computer systems. Expertise in microcontroller design is needed, familiarity with SONET and ATM technologies a plus. **Dept. SO701/SHSE-YA**

VLSI Design Engineers

Design digital ASICs for high speed SONET/ATM multiplexing and switching systems, and network interfaces. Responsibilities include logic design, verification, circuit and physical design, test and characterization and participation in system architecture definition. Requires an MS in EE, CS, CEE, or equivalent, and at least 2+ years' industry experience in custom CMOS circuit design. CAD tool expertise and a working knowledge of principles of telecommunications and data communications/LAN a must, familiarity with Cadence tools and experience in ATM or SONET technologies a plus. **Dept.SO701/VDE-YA**

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B

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Calendar

Signal Processing (NN, SP); Sept. 6–8; Porto Hydra Resort Hotel, Ermioni, Greece; Jeng-Neng Hwang, EE Department, FT-10, University of Washington, Seattle, WA 98195; 206-685-1603; fax, 206-543-3842.

Marine Technology Society Conference and Exposition (OE); Sept. 7–9; Convention Center, Washington, D.C.; Beth Cain, J. Spargo & Associates, 4400 Fair Lakes Court, Fairfax, VA 22033; 703-631-6200; fax, 703-818-9177.

International Electronic Manufacturing Technology Symposium (CPMT); Sept. 11–14; Hyatt Regency Hotel, La Jolla, Calif.; Michael P. Cassidy, AT&T Microelectronics Power Systems, 300 Skyline Dr., Mesquite, TX 75149; 214-284-2100; fax, 214-284-8182.

European Solid-State Device Research Conference (ED); Sept. 11–15; Heriot-Watt University, Edinburgh, Scotland; Jackie Butler, Institute of Physics, 47 Belgrave Square, London SWIX 8QX, England; (44+71) 235 6111; fax, (44+71) 259 6002.

Petroleum and Chemical Industry Technical Conference—PCIC '94 (IA); Sept. 12–14; Hyatt Regency Hotel, Vancouver, B.C.; S.W. Hagemoen, Universal Dynamics, 900–1441 Creekside Dr., Vancouver, BC V6J-4V3, Canada; 604-736-3381.

2nd Workshop on Speech Synthesis (SP); Sept. 12–15; Mohonk Mountain Lodge, New Paltz, N.Y.; R.Sproat, AT&T Bell Labs, Room 2D-451, 600 Mountain Ave., Murray Hill, NJ 07974; 908-582-5296; fax, 908-582-7308; e-mail, rws@research.att.com.

International Conference on Intelligent Robots and Systems—IROS '94 (IE, RA); Sept. 12–16; Universitat der Bundeswehr Munchen, Neubiberg, Germany; Volker Graefe, UniBwM, 8014 Neubiberg, Germany; (49+89) 6004 3590/3587; fax, (49+89) 6004 3074.

Oceans '94 (OE); Sept. 13–16; Parc Penfeld, Brest, France; Ginette Bonami, SEE, 48 rue de la Procession, F-75724 Paris, Cedex 15, France; (33+1) 44 49 60 60; fax, (33+1) 44 49 60 44.

Seventh European Signal Processing Conference—Eusipco '94 (SP); Sept. 13–16; University of Edinburgh, Scotland; Colin F.N. Cowan, Eusipco '94 Secretariat, Department of Electronic and Electrical Engineering, University of Technology, Loughborough, Leics. LE11 3TU, Britain; (44+509) 223 468; fax, (44+508) 222 830.

International Broadcasting Convention—IBC '94 (BT, Region 8, et al.); Sept. 16–20; RAI Congress Centre, Amsterdam, the Netherlands; IBC Secretariat, c/o IEE, Savoy Place, London WC2R OBL, England; (44+71) 240 3839; fax, (44+71) 497 3633.

International Symposium on Compound Semiconductors (ED, LEO); Sept. 18–22; Del Coronado Hotel, San Diego, Calif.; James Harbison, Bellcore, 331 Newman Springs Rd., Room 3X-211, Red Bank, NJ 07701; 908-758-3386; fax, 908-758-4372.

International Symposium on Ultra Clean Processing of Silicon Surfaces (ED); Sept. 19–21; Johns Hospital, Bruges, Belgium; Marc Heyns, IMEC, Kapeldreff 75, B-3001 Leuven, Belgium; (32+16) 28 12 48; fax, (32+16) 28 12 14.

Application Specific ICs Conference & Exhibit (C, Rochester Section); Sept. 19–23; Rochester Riverside Convention Center, New York; L. M. Engelbrecht, Rochester Engineering Society, 1806 Lyell Ave., Rochester, NY 14606; 716-254-2350; fax, 716-254-2237.

14th International Semiconductor Laser Conference (LEO); Sept. 19–23; Hyatt Regency Maui, Hawaii; S. Phillips, IEEE/LEOS,

Calendar

445 Hoes Lane, Box 1331, Piscataway, NJ 08855-1331;908-562-3894; fax, 908-562-1571.

Autotestcon '94 (AES, IM, et al.); Sept. 20–22; Disneyland Hotel, Anaheim, Calif.; Robert Rassa, ManTech International, 150 S. Los Robles Ave., Suite 350, Pasadena, CA 91101; 818-577-7100; fax, 818-577-7102.

International Conference on Harmonics in Power Systems—ICHPS VI (PE); Sept. 21–23; University of Bologna, Italy; Gian Carlo Montanari, Instituto de Elettrotecnia Industriale, University of Bologna, Viale Risorgimento 2, 40136 Bologna, Italy; (39+51) 644 3471; fax, (39+51) 644 3470.

Canadian Conference on Electrical and Computer Engineering (Region 7); Sept. 25–28; World Trade and Convention Centre, Halifax, N.S.; C. R. Baird, Department of Electrical Engineering, Technical University of Nova Scotia, Box 1000, Halifax, NS, B3J 2X4, Canada; 902-420-7717; fax, 902-422-7535.

Visual Communications and Image Processing Conference—VCIP '94 (CAS); Sept. 25–28; Bismarck Hotel, Chicago; Society of Photo-Optical Instrumentation Engineers (SPIE), Box 10, Bellingham, WA 98227-0010; 206-676-3290; fax, 206-647-1445.

Second Workshop on Interactive Voice Technology for Telecommunications Applications (COM); Sept. 26–27; Sumitomo Hall, Kyoto, Japan; Sadaoki Furui, NIT Human Interface Laboratories, 3-9-11 Midori-cho, Musashino-shi, Tokyo 180, Japan; (81+422) 59 3910; fax, (81+422) 60 7808.

International Workshop on Advanced Teleservices and High-Speed Commu-nication Architectures—Iwaca (C, IE); Sept. 26–28; IBM European Networking Center, Heidelberg, Germany; Alfred C. Weaver, Department of Computer Science, Thornton Hall, University of Virginia, Charlottesville, VA 22903; 804-982-2201; fax, 804-982-2214.

16th Electrical Overstress/Electrostatic Discharge Symposium—EOS/ESD (CPMT); Sept. 27–29; Riviera Hotel, Las Vegas, Nev.; ESD Association, 200 Liberty Plaza, Rome, NY 13440; 315-339-6937.

Wescon '94 (Region 6 et al.); Sept. 27–29; Anaheim Convention Center, California; Electronic Conventions Management, 8110 Airport Blvd., Los Angeles, CA 90045-3194; 800-877-2668; fax, 310-641-5117.

International Professional Communi-cation Conference—IPCC '94 (PC); Sept. 28–30; Banff Centre, Alta., Canada; Pamela R. Kostur, SaskTel, 3-2121 Saskatchewan Dr., Regina, SK S4P 3Y2, Canada; 306-777-2894.

OCTOBER

Sixth Digital Signal Processing Workshop (SP); Oct. 2–4; Yosemite Lodge, Yosemite National Park, Calif.; Mark J.T. Smith, School of Electrical Engineering, Georgia Institute of Technology, Atlanta, GA 30332-0250; 404-894-6291; fax, 404-894-8363; e-mail, mjts@eedsp.gatech.edu.

International Conference on Systems, Man, and Cybernetics (SMC); Oct. 2–5; Gonzalez Convention Center, San Antonio, Texas; Frank DiCesare, Rensselaer Polytechnic Institute, Troy, NY 12180-3590; 518-276-6440; fax, 518-276-6261; e-mail, dicesare@ecse.rpi.edu.

PROGRAM DIRECTOR

INDUSTRY, TELECOMMUNICATIONS, AND COMMERCE

The Office of Technology Assessment, a science and technology policy support agency of the U.S. Congress, has opened a search to fill the position of Program Director for the Agency's Industry, Telecommunications, and Commerce Program (ITC) to be created in the fall of 1994. The ITC Program will assume many of the responsibilities of the current agency programs in Telecommunications and Computing Technologies and in Industry, Technology and Employment. The Program Director is a member of OTA's senior management, responsible for developing both staff and policy directions for studies on technology and international industrial competitiveness, telecommunications and computing technologies, the national information infrastructure, international trade, industry productivity, and related topics. All studies will reflect the Agency's statutory mission, which is to analyze the implications of the application of technology, at the request of Committees of the Congress.

The ITC Program Director will be one of the Agency's six program directors, and will report directly to the Assistant Director for Industry, Commerce, and International Security. The position responsibilities include management of approximately 30 highly-skilled policy researchers, which will require ■ strong ability to lead, build, support, and direct staff as well as proven ability to exercise quality control in research, critical analysis, synthesis, and delivery of polished final products for delivery to the Congress and the public. Experience in public policy and acquaintance with the legislative environment are also essential.

Applicants must have an advanced degree or equivalent experience in a relevant technical or policy area, research and management experience in a relevant field, good interpersonal skills, no pre-determined legislative or policy agenda, and a high energy level. Submit curriculum vitae, list of references, and a letter indicating strengths by July 15, 1994 to:

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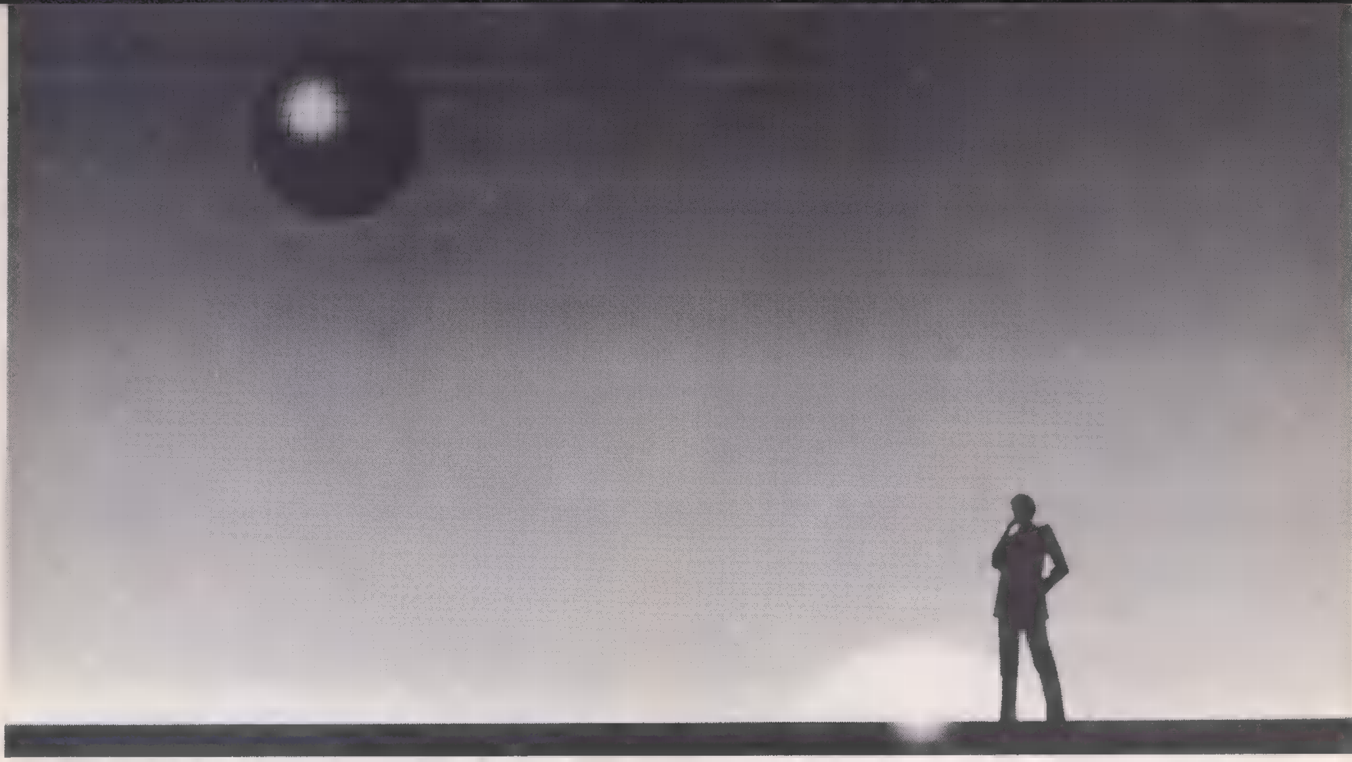

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Program notes

Multimedia audio for less

Market forces and low-cost technology between them have forced the multimedia market to adopt a multi-tiered standard for audio. Early multimedia enthusiasts assumed that all sound would be stored in the MIDI format. Cards and hardware for this Musical Instrument Device Interface, which is universally used by musicians and audiophiles, are technically superior to other formats for generating quality sound, but the cards and sound-generating devices are expensive.

Enter Microsoft's Windows Sound System, whose focus has been shifted from MIDI to the lower-cost WAV formats in the newest version of the Windows Sound API (application programming interface). In fact, most multimedia applications outside the high end now support the WAV format, which stores sound in [redacted] sampled pulse-code–modulated format borrowed from the audio compact disc (CD).

In general, of course, higher resolutions and sampling rates enhance the reproduced sound. Monaural 8-bit sound sampled at 11.025 kHz sounds much like the telephone or AM radio. Stereo 16-bit sound sampled at 44.1 kHz resembles [redacted] CD or FM radio.

WAV files also give multimedia developers leeway in packaging sound with their applications. They can store two minutes of AM-radio quality on a high-density floppy disk or an hour of FM-radio quality on [redacted] CD. As for price, a SoundBlaster-clone WAV card is US $100–$150, and [redacted] MIDI card $350–$500.

Microsoft's Windows Sound System now supplies tools for creating, editing, manipulating, and playing sound in WAV files. Some speech recognition software is also shipped with the system. *Contact: Microsoft Corp., One Microsoft Way, Redmond, WA 98052; 206-882-8080; or* **circle no. 101**.

A font of font knowledge

When it comes to electronic documents, what you see isn't always what other people get. Even though everybody who gets the document may use the same brand of software (a word processor like Microsoft's Word, for instance), one of the recipients may not have the typeface used to create the document installed on their system. So, that recipient's program will substitute a default typeface; in all likelihood, this substitution will change the document's formatting in undesirable ways, by inserting page breaks in unexpected places, for example.

A better solution would be to substitute a typeface whose characteristics are very similar to the original. Some time ago, ElseWare Corp. developed two technologies for identifying and then creating alternative typefaces, and made them available to the makers of laser printers and other equipment manufacturers. Now the company has brought out Font Works, the first end-user product for re-creating fonts.

The system utilizes the earlier ElseWare developments, Panose numbers and Infinifont. Panose numbers are [redacted] scheme for identifying typefaces by their visual characteristics. Each script (Latin, Cyrillic, and so on) and each class of type (text, display, decorative, and so on) has been assigned a unique Panose classification system.

(Continued on p. 62)

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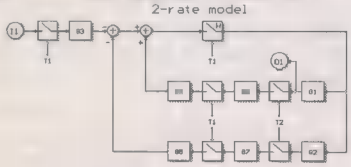

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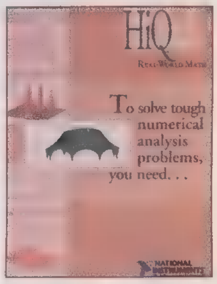

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Program notes

(Continued from p. 59)

Panose Level I is a number, made up of ten 4-bit segments (nibbles), that identifies a typeface's main attributes. Panose Level II is a 36-segment scheme for identifying a broader range of attributes of many more typefaces, a number of which may not be well known.

Panose numbers are embedded in all TrueType and PostScript fonts. Hewlett-Packard Co. and other laser printer makers also use Panose numbers, plus Infinifont, to manage built-in and down-loaded fonts.

Infinifont sends the font engine information from Panose files, plus a file called terafont that contains the basic typography information. The engine uses these inputs to generate characters that possess the attributes called for by a specific Panose number. In this way, Panose numbers are used to reverse-engineer fonts that would otherwise be unavailable.

One useful side effect of Infinifont is the enormous space savings that it offers to those desirous of using many typefaces in their documents. ElseWare's Font Works is a good example. The Infinifont technology enables it to store 150 typefaces—plus another 2500 typefaces described in Panose files—in approximately the same amount of space as is occupied by 20 Postscript Type 1 or TrueType fonts! *Contact: ElseWare Corp., 101 Stewart Street, Suite 700, Seattle, WA 98101; 206-448-9600; or* **circle no. 102.**

Maneuvering through cyberspace

The Internet's intricacies can overwhelm a novice. But some basic software tools will simplify any voyage into cyberspace.

Telnet is a terminal emulation program for logging on to a computer on the Internet as if the machine were on the local network. It requires logon IDs and passwords.

A File Transfer Protocol (FTP) user can down- and upload files from and to an Internet computer. Again, logon IDs and passwords are usually required, though some servers offer anonymous FTP: users log on with the generic ID "anonymous" plus their own choice of password.

Four other tools—Mail, News, Gopher, and Uucode—open up more of the Internet's capability to users. Mail equips users to send and receive mail (obviously), provided they have access to a POP3 (post office protocol 3) mail server. Such servers are not identical, so users should ask which mail packages support their local unit.

News is for reading and posting news; while the noncommercial Usenet is the most popular news service, there are many others. Gopher searches for and retrieves information about specific topics on gopher servers, developed by universities, institutions, and businesses and all on Internet. Finally, Uucode converts 8-bit character files into a format suitable for transmission over a network that recognizes only 7-bit characters. It can also convert any Uucode-encoded files received to 8-bit format.

Most of the tools may be bought in a block. Thus Windows versions of all of them are sold as part of Spry Inc.'s Air Series. But the Spry Mail program requires a very sophisticated POP3 server unavailable to most users.

The "sure to work on any POP server" mail program is Qualcomm Inc.'s Eudora, available in both PC and Mac versions. A limited shareware version can be downloaded from most bulletin boards. Ease-of-use features, however, make the full commercial version of Eudora a better buy. *Contact: for the Air Series, Spry Inc., 316 Occidental Ave., South Suite 200, Seattle, WA 98014, 206-447-0300; or* **circle no. 103;** *for Eudora, Qualcomm Inc., 6455 Lusk Blvd., San Diego, CA 92121-2779; 800-2EUDORA in the United States, 619-587-1121 elsewhere, and ask for the Eudora sales group; or* **circle no. 104.**

CONTRIBUTOR: John R. Hines is a silicon sensor engineer at Honeywell Inc.'s Micro Switch Division, Richardson, Texas.
CONSULTANT: Bruce Mather, Phototelesis Corp.

acquisition peripheral [to the left of the PC] connects to the latter through the PC's parallel printer port. It is capable of digitizing eight single-ended or four differential input channels.

As notebook-size personal computers gain in popularity, interest is also rising in compact data-acquisition boxes to work with them. These boxes are helpful in a variety of situations, from gathering field data—monitoring engine parameters in a moving car, for example—to simply fitting onto a crowded workbench. The latest such unit is the DAQPad-1200 from National Instruments Corp. [photo].

The device is a lightweight (0.77 kg) peripheral measuring just 14.6 by 21.3 by 3.8 cm. At its heart is a 12-bit analog-to-digital converter capable of 100 000 conversions a second. Its eight single-ended analog inputs may be configured as four differential channels. Other features are a programmable-gain amplifier, a buffer for up to 2000 digitized samples, 24 digital I/O lines, and three 16-bit counter-timer channels.

The DAQPad-1200 is configured and calibrated entirely by means of software commands; no jumpers or trimming potentiometers are needed. It can sample in several modes, under external control or with internally controlled interval scanning. With the latter, the unit scans all activated input channels at a user-programmable rate, waits for a user-selected interval, and then repeats the scan.

The DAQPad-1200 works with both the standard (Centronics) parallel printer port and the faster Enhanced Parallel Port (EPP). Bundled with it are National Instruments' DAQWare and NI-DAQ software. DAQWare is a menu-driven, DOS-based system for

Designed for production, burn-in, and reliability testing applications, the PS2500 family of programmable power supplies is well suited for use in low-cost computer-controlled systems. At present, the family has four members, two of which are programmed through front-panel controls and two otherwise identical units, which may also be programmed over the general-purpose interface bus (IEEE 488.2).

The model 2510 [photo] and its bus-programmable version, the 2510G, provide 0–36 V at up to 3.5 A. The 2511 and 2511G offer 0–20 V and up to 7 A. The four supplies allow the user to automate repetitive tests by programming up to 100 combinations of voltage, current, and timing. They all offer both constant-voltage and constant-current modes.

For each supply, voltages may be programmed with 10-mV resolution and read to within 0.025 percent plus 25 mV. Current resolution is 1 mA, and current accuracy is 0.2 percent plus 10 mA. Time intervals can be set from 1 to 65 535 seconds.

Line regulation is better than 0.03 percent plus 6 mV for voltage, 0.1 percent plus 6 mA for current. Load regulation for

The 2510 programmable power supply from Tektronix delivers up to 36 V and up to 3.5 A. It can store up to 100 combinations of voltage, current, and time interval.

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nd 2511 are priced at $895.
nable versions go for $1095.
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Box 1520, Pittsfield, MA
6-2200; or **circle 113.**

dium frequency counter

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ed of extremely accurate fre-
rements in the field. So the
offering its Model PM 6685R
base frequency counter/cali-
a practical field instrument
s well as accurate, one of the
counter's key specifications is its warm-up time: after just six minutes, it can make measurements to within 1 part in 10^9. Moreover, after 30 minutes, it reaches 1 part in 10^{10}. The instrument drifts less than 5 parts in 10^{11} per month and less than 5 parts in 10^{10} per year.

The counter/calibrator's standard input frequency range goes up to 300 MHz. Options then extend that range to 1.3, 2.7, or 4.5 GHz, so that high-resolution digital calibration measurements can be made at high frequencies without the complexities associated with synthesizers, mixers, and filters.

The PM 6685R has a list price (in the United States) of $10 645. *Contact: Fluke Corp., Box 9090, Everett, WA 98206; 206-356-5500; toll-free, 800-44-FLUKE; fax, 206-356-5116; in Europe, Fluke Europe B.V., Box 1186, Eindhoven, the Netherlands; (31+40) 644-200; fax, (31+40) 644-222; or* **circle 114.**

DIGITAL SIGNAL PROCESSING

Inexpensive tools from Russia

Two low-cost development products for Motorola's 16-bit DSP56166 (and DSP56156) digital signal processor have been developed by a team of six engineers in Moscow and are being offered for sale in the United States by The Accolade Group. These are the DS-56166 application development system and the CC-561XX OnCE command converter.

The DS-56166 was designed for speech-processing applications, which need small size, ease of use, and simple operation. It is platform-independent and may in fact be controlled by any computer with an RS-232 interface. Thus the same unit will work with

Program r

(Continued from p. 59)

Panose Level I is a numb
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One useful side effect of
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their documents. ElseWare's Font Works is a good example. The Infinifont technology enables it to store 150 typefaces—plus another 2500 typefaces described in Panose files—in approximately the same amount of space as is occupied by 20 Postscript Type

are not identical, so users should ask which mail packages support their local unit.

News is for reading and posting news; while the noncommercial Usenet is the most popular news service, there are many others. Gopher searches for and retrieves

Eudora sales group; or **circle no. 104.**

CONTRIBUTOR: John R. Hines is a silicon sensor engineer at Honeywell Inc.'s Micro Switch Division, Richardson, Texas.
CONSULTANT: Bruce Mather, Phototelesis Corp.

EEs' tools & toys

PC data-acquisition unit connects to parallel ports

National Instruments' DAQPad-1200 data-acquisition peripheral [to the left of the PC] connects to the latter through the PC's parallel printer port. It is capable of digitizing eight single-ended or four differential input channels.

As notebook-size personal computers gain in popularity, interest is also rising in compact data-acquisition boxes to work with them. These boxes are helpful in a variety of situations, from gathering field data—monitoring engine parameters in a moving car, for example—to simply fitting onto a crowded workbench. The latest such unit is the DAQPad-1200 from National Instruments Corp. [photo].

The device is a lightweight (0.77 kg) peripheral measuring just 14.6 by 21.3 by 3.8 cm. At its heart is a 12-bit analog-to-digital converter capable of 100 000 conversions a second. Its eight single-ended analog inputs may be configured as four differential channels. Other features are a programmable-gain amplifier, a buffer for up to 2000 digitized samples, 24 digital I/O lines, and three 16-bit counter-timer channels.

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The DAQPad-1200 works with both the standard (Centronics) parallel printer port and the faster Enhanced Parallel Port (EPP). Bundled with it are National Instruments' DAQWare and NI-DAQ software. DAQWare is a menu-driven, DOS-based system for configuring, monitoring, and controlling the DAQPad-1200 (and other National Instruments data-acquisition boards). NI-DAQ is a library of more than 110 data-acquisition functions for such boards. It also acts as a resource manager to eliminate address and interrupt conflicts in multiboard systems.

The DAQPad-1200 sells for US $995, including an ac adapter. A rechargeable battery pack is an extra $295. *Contact: National Instruments Corp., 6504 Bridge Point Parkway, Austin, TX 78730-5039; 512-794-0100; toll-free, 800-433-3488; fax, 512-794-8411 or 512-794-5678; or* **circle 111.**

INSTRUMENTATION

Programmable power supplies

Designed for production, burn-in, and reliability testing applications, the PS2500 family of programmable power supplies is well suited for use in low-cost computer-controlled systems. At present, the family has four members, two of which are programmed through front-panel controls and two otherwise identical units, which may also be programmed over the general-purpose interface bus (IEEE 488.2).

The model 2510 [photo] and its bus-programmable version, the 2510G, provide 0–36 V at up to 3.5 A. The 2511 and 2511G offer 0–20 V and up to 7 A. The four supplies allow the user to automate repetitive tests by programming up to 100 combinations of voltage, current, and timing. They all offer both constant-voltage and constant-current modes.

For each supply, voltages may be programmed with 10-mV resolution and read to within 0.025 percent plus 25 mV. Current resolution is 1 mA, and current accuracy is 0.2 percent plus 10 mA. Time intervals can be set from 1 to 65 535 seconds.

Line regulation is better than 0.03 percent plus 6 mV for voltage, 0.1 percent plus 6 mA for current. Load regulation for voltage is better than 3 mV (rear output) or 6 mV (front output). For current, the regulation is better than 3 mA, except for currents above 3.5 A (2511 and 2511G), in which case it rises to 6 mA.

The 2510 programmable power supply from Tektronix delivers up to 36 V and up to 3.5 A. It can store up to 100 combinations of voltage, current, and time interval.

The 2510 and 2511 are priced at $895. The programmable versions go for $1095. *Contact: Tektronix Inc., Test and Measurement Group, Box 1520, Pittsfield, MA 01202; 800-426-2200; or* **circle 113.**

Portable rubidium frequency counter

Cellular communications and other new areas are in need of extremely accurate frequency measurements in the field. So the Fluke Corp. is offering its Model PM 6685R rubidium timebase frequency counter/calibrator. Since a practical field instrument must be fast as well as accurate, one of the counter's key specifications is its warm-up time: after just six minutes, it can make measurements to within 1 part in 10^9. Moreover, after 30 minutes, it reaches 1 part in 10^{10}. The instrument drifts less than 5 parts in 10^{11} per month and less than 5 parts in 10^{10} per year.

The counter/calibrator's standard input frequency range goes up to 300 MHz. Options then extend that range to 1.3, 2.7, or 4.5 GHz, so that high-resolution digital calibration measurements can be made at high frequencies without the complexities associated with synthesizers, mixers, and filters.

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DIGITAL SIGNAL PROCESSING

Inexpensive tools from Russia

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The DS-56166 was designed for speech-processing applications, which need small size, ease of use, and simple operation. It is platform-independent and may in fact be controlled by any computer with an RS-232 interface. Thus the same unit will work with

Tools & toys

Macintosh computer or any Unix workstation, as well as with an IBM-type PC. A single system costs as little as $695.

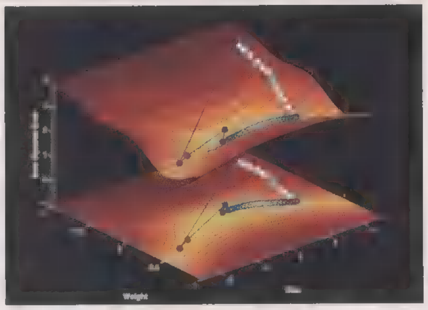
The CC-561XX converts RS-232 commands from the host computer into a format compatible with the Motorola OnCE interface for on-chip emulation. It therefore provides emulation capability for prototype products built around a DSP56166, with no need for an expensive processor replacement cable. Normally bundled with the DS-56166, the command converter may be purchased separately for $335. Its Quick-Bug software development shell is compatible with all major PCs and workstations, according to Accolade.

To make DSP technology available to a wide range of users—especially engineering students and faculty—discounts on both products are offered to qualified members of the academic community. *Contact: The Accolade Group Ltd., 1695 Sherwood Rd., Highland Park, IL 60035; 708-831-3009; fax, 708-831-4854; or* **circle 112.**

SOFTWARE

Faster neural net training

The MathWorks Inc. has introduced version 2.0 of its Neural Network Toolbox, an add-on to the company's popular Matlab technical computing environment. One of the enhancements in the new toolbox is the use of the Levenberg-Marquardt algorithm to speed the training of back-propagation networks by a factor of ten. The faster training should add to the technology's appeal for real-world applications that involve loads of data—noise cancellation, industrial process control, pattern recognition, and financial forecasting, for example.



This Matlab plot compares training rates for conventional back-propagation [white, 108 steps] and the fast Levenberg-Marquardt algorithm [blue, five steps]. Each trace illustrates the number of steps from initial conditions to the minimum error.

In addition, version 2.0 incorporates several new network architectures, including radial basis functions, Elman recurrent networks, adaptive linear networks, and learning vector quantization. It also meshes with the company's Simulink nonlinear dynamic simulation environment, which takes some of the toil out of neural networks embedded in their target systems.

Single-user pricing for the Neural Network Toolbox starts at $895 for use with PCs. Versions are also available for Apple Macintoshes, Sun SparcStations, IBM RS/6000s, Hewlett-Packard Series 700 machines, Silicon Graphics workstations, and several systems from Digital Equipment Corp. The toolbox requires Matlab 4.0 or above. *Contact: The MathWorks Inc., 24 Prime Park Way, Natick, MA 01760-1500; 508-653-1415; fax, 508-653-2997; e-mail, info@mathworks.com;via the World Wide Web, http://www.mathworks.com; or* **circle 117.**

DATA ACQUISITION

A compendium of software solutions

From Data Translation Inc., the well-known maker of data-acquisition and imaging products, has just come its *1994 Product Handbook.* The 320-page catalog describes the company's complete product line, with an emphasis on software—from programming tools to specific applications.

Also included are technical tutorials and

examples of products being used. The idea is to help users select the optimum combination of hardware and software for their needs.

The *1994 Product Handbook,* available now, is offered free of charge. *Contact: Data Translation Inc., Sales Department, 100 Locke Dr., Marlboro, MA 01752-1192; toll-free, 800-481-3700 (United States and Canada); otherwise, 508-481-3700; fax, 508-481-8620; or* **circle 115.**

GENERAL INTEREST

'Cruising' the Internet

Interested in meeting new people in a safe yet inexpensive way? If so, you may be interested in the latest ice-breaking wrinkle from California (where else?)—personalized Internet license-plate frames. These are black frames with the word "INTERNET" on top in white, and a personalized Internet address on the bottom, also in white.

Will these frames change your life? There is no guarantee, but it costs only $11 (plus $3.50 for shipping and handling) to find out. To order, simply send a check for $14.50 to DHM and write your e-mail address in the check's memo field. *Contact: DHM Information Management Inc., 409 N. Pacific Coast Hwy. #249, Redondo Beach, CA 90277; 310-214-3349; fax, 310-214-3090; e-mail, info@dhm.com.* or **circle 116.**

NEW AND NOTEWORTHY

- Analog Devices Inc., Wilmington, Mass., claims it has the first **silicon transimpedance amplifier** to meet the bandwidth, noise, and sensitivity specifications of 155-Mb/s data links. At $3.10 each in 1000-piece quantities, the 200-MHz AD8015 aims at asynchronous transfer mode network, fiber to the home, and fiber distributed data interface applications. **Circle 118**
- Burr-Brown Corp., Tucson, Ariz., has a "power miser" general-purpose **instrumentation amplifier for battery-driven systems** that operates with power supplies of ±1.35 V to ±18 V (single supply down to 2.7 V) and a quiescent current of only 350 µA. The INA118's three-op-amp design and eight-pin package sells for $3.25 each for one thousand pieces. **Circle 119**
- CSPI, Billerica, Mass., now offers a **multiprocessor VMEbus board** that relies on eight i860 processors to reach 640 MFLOPS. The SuperCard-4SLX, which costs $29 000, relies on National Semiconductor Inc.'s QuickRing controllers to provide I/O bandwidth scaling up to 1.2 GB/s. **Circle 120**
- Momentum Data Systems Inc., Costa Mesa, Calif., has what could be the first **DSP board for the PCI** (peripheral control interface) bus. Also offered for the ISA bus, the Eagle 56 boards are built around 40- and 66-MHz Motorola DSP56002 fixed-point DSP chips. They operate at 20 and 33 million instructions per second, respectively; have a high-speed parallel host interface optimized for 16- and 24-bit data transfers; and sport four banks of 64 k-by-24-bit zero-wait-state static RAM. The 40-MHz board is $2695, the 66-MHz is $3695. **Circle 121**
- Bus-Tech Inc., Burlington, Mass., has an **interconnect controller** for transferring multimegabytes per second between mainframes and server or workstation platforms. The Datablaster emulates a standard IBM tape control unit on the host side, while presenting SCSI tape signals to the workstation. Bidirectional data transfer bypasses the overhead associated with traditional protocol stacks such as SNA and TCP/IP. **Circle 122**
- Computer Products Inc., South Boston, Mass., has a new family of ultralow-noise, high-accuracy **5-W dc-dc converters.** Line and load regulation for the PM900 series is ±0.02 percent, transient response is 20 µs for 100 percent load steps. Price of the converters, which have a 5.1-by-5.1-by-1.0-cm footprint, is $50 apiece in large quantities. **Circle 123**

COORDINATOR: Michael J. Riezenman
CONSULTANT: Paul A.T. Wolfgang, Boeing Defense & Space Group

CLASSIFIED EMPLOYMENT OPPORTUNITIES

The following listings of interest to IEEE members have been placed by educational, government, and industrial organizations as well as by individuals seeking positions. To respond, apply in writing to the address given or to the box number listed in care of *Spectrum* Magazine, Classified Employment Opportunities Department, 345 E. 47th St., New York, N.Y. 10017.

ADVERTISING RATES

Positions open—$40.00 per line, not agency-commissionable.

Positions wanted—$40.00 per line, a 50% discount for IEEE members who supply their membership numbers with advertising copy.

All classified advertising copy must be received by the 25th of the month, two months preceding the date of issue. No telephone orders accepted. For further information call 212-705-7578.

IEEE encourages employers to offer salaries that are competitive, but occasionally a salary may be offered that is significantly below currently acceptable levels. In such cases the reader may wish to inquire of the employer whether extenuating circumstances apply.

Academic positions open

Grad Student Ph.D. Assistantships and possible assistant engineer or postdoctoral positions open for only highly experienced engineers in power quality, expert systems, and EMTP. Send resume with refs, telephone and GRE to Dr. Alex Domijan, Director, Florida Power Affiliates, Dept. of Electrical Engineering, Univ. of Florida, 323 Benton Hall, Gainesville, FL 32611. (904) 392-0290.

Gonzaga University in Spokane, Washington is seeking a faculty member with a strong background in software and hardware digital design, and electronics. Experience in the design of real-time embedded systems, object oriented programming and use of CASE tools is required. Industrial design experience, a publication record and teaching experience are considered important. Responsibilities include teaching in an ABET accredited BSEE program and an MSEE program. An appointment will be made at the assistant or associate professor level. Only citizens or permanent residents of the United States will be considered. Candidates must have completed a Ph.D. degree. Gonzaga University is a Catholic, Jesuit university with a commitment to teaching humanistic values to develop the whole person. The attractive, growing campus is set in an area of scenic beauty in the Inland Northwest. Send resume and list of three references to Dr. Raymond A. Birgenheier, Chair, Department of Electrical Engineering, Gonzaga University, 502 E. Boone Ave., Spokane, WA 99258. Screening of applicants will begin in early August 1994 and the expected appointment date is January 1, 1994. Gonzaga is an Equal Opportunity/Affirmative Action Employer.

Simon Fraser University, Ebco/Eppich NSERC Industrial Chair in Intelligent Software Systems: The Schools of Computing Science and Engineering Science in conjunction with the Centre for Systems Science at Simon Fraser University invite applications and nominations for this chair at the Assistant or Associate Professor level. Candidates must have an outstanding research record and a demonstrated record of industrial collaboration. Background in an Engineering discipline would be an asset. This chair is the more junior of two chairs dually funded by NSERC to complement an existing endowment from British Columbia industries (raised by the Eppich brothers of Ebco, ltd.). The Senior Chair is held by Dr. Hassan Aït-Kaci. The Junior Chair will collaborate with the Senior Chair, conducting research on designing intelligent software prototypes and developing applications. The Junior Chair candidate is expected to hold a PhD in Computing Science or related field with a few years of post-doctoral research experience. The required expertise is in symbolic and constraint-based programming and compiling, and advanced run-time environment development. Strengths and interests in data and knowledge base systems, real-time and concurrent programming, and graphical interface design are desirable. The chair appointment is for an initial five year period during which time a primary responsibility, in addition to academic research and the training of graduate students, will be participation with the Senior Chair in experimental projects in collaboration with industry. A five year extension of the chair appointment is possible. After the Chair appointment has expired, the individual will assume the responsibilities of a regular academic appointment. The academic appointment is tenure-track (or tenured if warranted). In accordance with Canadian immigration requirements, priority will be given to Canadian citizens and permanent residents of Canada. Simon Fraser University is committed to the principle of equity in employment and offers equal employment opportunities to qualified applicants. Applications will be accepted until September 1, 1994. To apply, send a curriculum vitae, evidence of research productivity (selected reprints), and the names, addresses and phone numbers of three referees to: Arthur L. Liestman, Director, School of Computing Science, Simon Fraser University, Burnaby, British Columbia, Canada, V5A 1S6. Fax: (604) 291-3045.

Research Associate: $30,000.00 per year, 40 hours per week. (1) Design and develop integrated spatial modeling systems which combines the use of GIS, expert systems and DBMS in natural resource management on both UNIX and PC platforms. Will use skills in UNIX, MS-DOS, GIS packages (ARC/INFO and GRASS), C, CLIPS, computer networks and Oracle DBMS to perform these duties. (2) Coordinate natural resource management projects of STARR Lab with co-operators from U.S. and Taiwan. (3) Organize and conduct workshops and training programs for resource agencies in U.S. and Taiwan. (4) Supervise 2 graduate students and 2 student workers in conducting research and fulfilling cooperate agreements with natural resource agencies in U.S. and Taiwan. Requires Ph.D. in Engineering or Computer Science and (1) at least one degree in an Agriculture, Forestry, or Ecology-related field; and (2) written and verbal proficiency in English and Chinese. Apply at the Texas Employment Commission, Bryan, Texas, or send resume to the Texas Employment Commission, TEC Building, Austin, Texas 78778, J.O. #TX6864201. Ad Paid by an Equal Opportunity Employer.

Harris Professor of Computer Science, Florida Institute of Technology: Florida Tech is seeking a nationally recognized scholar and researcher to fill the Harris Professorship of Computer Science. Qualifications include an earned doctorate in Computer Science, Computer Engineering, or related fields, and a record of excellence in teaching and research. Candidates should demonstrate experience and credentials for advanced research in a specific area within the discipline. Experience in government or industrial settings is highly desirable. The candidate will be expected to assume a leadership role in the development and enhancement of Computer Science research and teaching activities at Florida Tech. In addition, the candidate will have unique access to the Harris Corporation and be expected to coordinate research and educational efforts in areas of mutual interest. Florida Institute of Technology, founded in 1958, is an independent and fully accredited technological university located on Florida's space coast. Approximately 5,000 students are enrolled with about 3,200 students at the 175-acre Melbourne campus and 1,800 at Florida Tech's off-campus graduate centers. The university has five academic units: the College of Engineering, the College of Science and Liberal Arts, the School of Aeronautics, the School of Business, and the School of Psychology. The Computer Science program is part of the Division of Electrical and Computer Science and Engineering in the College of Engineering. Salary is commensurate with experience and qualifications. Application package should include: 1) letter of application; 2) detailed curriculum vitae; and 3) a list containing the names, addresses, and telephone numbers of at least three persons who may be contacted for verbal and written comment. Applications and nominations should be submitted to: Florida Institute of Technology, Dr. Louis A. Martin-Vega, Chair, Harris Professor Search Committee, College of Engineering, 150 W. University Blvd., Melbourne, FL 32901-6988. The appointment will be made during the 1994-'95 academic year. The screening process will begin on August 15, 1994 and conclude when an appropriate candidate has been selected. Florida Tech is an Equal Opportunity/Affirmative Action Employer.

Ames Laboratory, Associate Mathematician, Ames Laboratory, Iowa State University: The Applied Mathematical Sciences research program of the Ames Laboratory is seeking an Associate Mathematician to conduct advanced scientific research in the area of transient direct and inverse scattering. The incumbent will develop theoretical models and computer codes that implement those models, and present written and oral justification for all aspects of research. Position requires a Ph.D. in Applied Mathematics, Mathematics or related field plus previous research experience in the area of direct and inverse scattering. Salary: $37,442 minimum. Candidates should submit cover letter, complete, detailed resume, plus the names and addresses of three references to: Ames Laboratory Personnel Office, 127 Spedding Hall, Iowa State University, Ames, IA 50011. Application deadline of August 15, 1994, or until position is filled. An equal opportunity/affirmative action employer.

Korea University: The Department of Electronics Engineering invites applications for three faculty positions at all levels in the areas of communications, semiconductor devices, and information processing. Outstanding applications in other areas will also be considered. All candidates must have a Ph.D. degree and strong research and teaching capabilities. These positions are for the spring semester beginning March 1, 1995. Please send a detailed resume: Chairperson, Department of Electronics Engineering, Korea University, 5 Ga-1 Anam-dong Sungbuk-gu, 136-701, Seoul, Korea.

Government/Industry Positions Open

Product Manager, by August 1, 1994, Please Send Resume To: Employment Security Department, E&T Division, Job # 427643-B, P.O. Box 9046, Olympia, WA 98507-9046. Job Order Number must be indicated on your response. Job Description: Plans, develops, and manages marketing activities for desktop publishing software. Marketing activities include product launch and continued marketing support, including mass marketing and marketing to educational, small business, and non-profit market segments. Makes presentations to distributors, user groups, media, and industry events. Plans and defines market and technical requirements for new product versions and new products. Evaluates third party technologies for inclusion in future versions of consumer software applications products. Develops proposals and negotiates contracts for joint marketing efforts with third party subcontractors and vendors of complimentary products. Requirements: Master's degree in Business or Marketing; 2 years work experience in job offered or in technical marketing of computer, electronics, or

telecommunication products and making technical presentations to high level mangers, to include 6 months of experience making recommendations for computer, electronics or telecommunication product design, and 6 months of work experience or equivalent school project experience developing consumer or educational software applications products. Experience may be gained concurrently. 20 course hours in computer science and electrical engineering. Must have legal authority to work in the United States. Job Location: Seattle area employer. Salary: $45,000 - $52,000 per annum, depending on experience. Compensation package includes bonuses and stock options. 40 hours per week, flex time. EOE

Sr. Elec. Engr.: Exp'd in design development power electronic products such as AC/DC power supplies, AC/AC converters in power ratings to 100 kw. Exp. in use of microprocessors, switching technology, etc., in designs is required, along with exp. with DSP. Position requires some proposal writing, customer contact, personnel supervision. Education minimum BSEE. Minimum 6+ years work exp. in this field. Live and work on Florida's Gulf Coast. Excellent opportunity. Send resume to Trilectron Industries, Inc., 12297 US 41 N, Palmetto, FL 34220-2504.

Designer, Senior Analog Electronics: Permanent position with growing U/S OEM supplier of low to medium power drivers for ultrasonic horns. Experience must include switching power supplies, sophisticated auto-tuning, low level signal conditioning and magnetics. Call or fax: Med Tech Products, Laguna Hills, CA. Tel (714)768-3535, Fax (714)768-2136.

Engineer, Performance Architecture Tools Specialist: Develop and implement processor & operating system simulation and performance analysis framework & methodology for 80x86 architecture & extensions. Develop C/C++ code, source code management, resolve OS portability issues. Must have Ph.D. in C.S. or E.E. and advanced academic research or project background in design methodology for VLSI design automation, including design representation framework for architectural analysis, modeling, microarchitecture tradeoff analysis, CAD and system simulation tool development, performance evaluation, and development of UNIX device drivers and application software. Also requires advanced academic background in ASICs development, UNIX software development, OS internals, project design management, and C, C++, UNIX kernel. $5,508.33/mo., 40 hrs./wk. Place of employment and interview: Santa Clara, CA. Send this ad and your resume to: Job Order #SB 38166, P.O. Box 269065, Sacramento, CA 95826-9065. The company is an equal opportunity employer and fully supports affirmative action practices.

A Project Director is needed in Dallas, Texas to implement and coordinate through support staff the sale of various electronic systems to customers. Analyze, evaluate and present information concerning business situations, production capabilities, manufacturing problems and design and development of products to be manufactured, prepare proposals of products to be manufactured by computer aided manufacturing based upon specs and transmit to home office. Monitor development schedules, component selection, prototype testing, governmental regulations, materials procurement, manufacturing schedules, production problems, testing and inspection of procedures and quality assurance. Review technical problems and recommends solutions to customers. Consult with company engineers in home office about quality assurance of designed products to rectify problems. Must have a Bachelor's Degree in Engineering or equivalent. Must have two years experience in job offered, and two years experience as a Project Manager of product development. Must submit c.v. Must be fluent in Chinese language which is required 100% of the time with Hong Kong or China plants. Within two years, must have experience in systems engineering, manufacturing engineering, operations management and quality assurance systems. Apply at the Texas Employment Commission, Dallas, Texas, or send resume to the Texas Employment Commission, TEC Building, Austin, Texas 78778, J.O. #TX6886424. Ad Paid by An Equal Opportunity Employer.

Applications Software Engineer: Analyzing and developing software codes for Programmable Logic Controllers, Variable Frequency and vector controlled AC drives and DC servo drives. Designing, developing and implementing control systems for automated manufacturing processes. Operating and working with Autocad and expanding its library. Use of SYSTEX, ECC, C, VISUAL BASIC, Microsoft Excel and various other customized language libraries. System design also includes drive sizing, speed and position control for customer's motion profile. Req'd Bachelors Degree in Electrical Engineering with 4 mos. exp. in the job or 4 mos. exp. in related occupation such as Graduate Research Assistant. Also req'd related experience in the area of design and analysis of controllers for tracking. Must have experience in C. Graduate level courses one each in: Introduction to Robotic Systems; Numerical Analysis; Optimization Methods for Systems Control; Lumped System Theory. Thesis in the area of design of a controller for smooth pursuit tracking. 40 hrs/wk 8:00 am - 5:00 pm. $36,000/yr. Send resume to 7310 Woodward Ave., Rm. 415, Detroit, MI 48202, Ref.#28294. "Employer Paid Ad".

Senior Staff Engineer for so. central Ohio mfr. Responsible for design of laser positioning devices for construction layout & industrial measurement. Function as systems engineer on software, electronic system nodules, related accessories. Product development work from initial concept through production. MS/EE or MS/CE. Six yrs. exp. which must have entailed primary emphasis on microprocessor electronics & software & have involved: design of laser positioning devices for construction layout, surveying & industrial measurement; integrating electronic & software modules into complete systems & accurate measuring devices; & hardware programs from initial concept design through product production, relating to construction layout, surveying & industrial measurement. In lieu of MS/EE or MS/CE, will accept an additional 4 yrs. of exp. as an electrical or civil engineer, provided candidate possesses 6 yrs. of exp. as described above. 8am-5pm. $65,741/yr. Must have proof of legal authority to work indefinitely in U.S. Send resume in duplicate (no calls): K. Shockey, JO#00365, Ohio Bureau of Employment Services, P.O. Box 1618, Columbus, OH 43216.

Electronic Engineer: Hands on RF and analog circuit design in the 2-100 Mhz range for video/communications applications. Require RF circuit board design experience. Familiarity with digital signal processing techniques and systems analysis software a plus.
Senior Electronic Engineer: Over 5 years experience in digital circuit design and microprocessor interfacing. Assembly language, Ethernet protocol and CAD/CAE experience desirable. Unique opportunity to join rapidly growing, paradigm-busting startup. Resumes to John Artman, Elcom Technologies Corp., 5 Great Valley Parkway, Suite 356, Malvern, PA 19355.

Senior Experimental Engineer/Wireless Communications Analyst: 40 hours/week, 8 a.m. - 5 p.m.; $42,500/year; overtime as needed, not compensated. Job requires either: 1) Master's degree in Electrical Engineering and 1 year experience as an Electronic Systems Design Engineer or 2) Bachelor's degree in Electrical Engineering and 2 years experience as an Electronic Systems Design Engineer. Job also requires: 1) Experience must include 6 months experience designing and developing digital and mixed signal Application Specific Integrated Circuitry (ASIC); 2) Experience must include 1 year experience developing automotive communications interface electronics; 3) Experience must include 1 year experience testing vehicle communication protocols for automotive applications implemented by U.S., European and Asian automotive manufacturers; 4) Experience must include 1 year experience participating with the Society of Automotive Engineers' SAE J1850 Multiplex Systems Committees; and 5) Experience must include 1 year experience optimizing electronic design to fit small lightweight enclosures. These experience requirements may be met currently during the same 1 year period. Job duties: Perform research in emergency radio frequency technologies for use in hand-held automotive test equipment. Conduct research in and perform analysis of noise, electromagnetic susceptibility, and radiated emissions in vehicle service center environments. Perform feasibility studies for equipping vehicle diagnostic equipment with radio frequency capabilities. Determine technical implementation feasibility and cost performance analysis to equip vehicle service center environments with radio frequency communication systems which are applicable for vehicle service repair processes. Research common local area network solutions which would be applicable for North America, the European Community, and Eastern Europe. Coordinate electromagnetic compatibility certification for portable vehicle diagnostic test tool in the world market. Design and test prototype power circuitry using ASIC. May exercise technical discretion over a small group of engineers and technicians. Qualified applicants should send resume and verification of requirements to: 7310 Woodward, Room 415, Detroit, MI 48202. Ref. #7794. An Equal Opportunity Employer. Employer Paid Ad.

EE Digital Communications: R&D Position - Florida. Motorola's Paging Products Group has an immediate opening for an experienced EE Digital Communications Technologist to work at our Boynton Beach, Florida location. Qualified candidate will possess a M.S. or Ph.D and 4-6 years experience in digital communications technology R&D, with emphases on digital modulation and Error Correcting Coding in mobile RF environment. Knowledge of hardware implementation issues, trade offs in digital modulations, RF digital communications systems and computer simulation tools are essential. For confidential consideration, please send resume to: Motorola Paging Products Group, Attn: Staffing Office, 1500 Gateway Blvd., Boynton Beach, FL 33426. An equal opportunity/affirmative action employer. We encourage minority, female, and disabled candidates to apply. No phone calls please!

Senior Research Software Engineer needed to lead all ORM research within the company, including specifying & developing architecture for new GUI ORM CASE tools; prototyping new aspects of ORM CASE tools; research & development of new algorithms, processes & languages for use in ORM tools; presenting research results in internationally referred journals & at internationally refereed conferences; and developing patents on ORM research. Requires: Bachelor's Degree in Computer Science with minimum of 20 semester (or 30 quarter) credit hours in ORM/NIAM methodology; 1 year research & development of GUI ORM/NIAM CASE tools; and publications on ORM/NIAM methodology presented at internationally refereed conferences or in internationally refereed journals. Resume/cover letter must reflect all requirements. Salary: $49,500.00/yr; 40 hours/week in Bellevue, WA. Send resume by August 1st, to: Job Order #427069, Employment Security Dept., E&T Div., PO Box 9046, Olympia, WA 98507-9046. EOE

Engineer, CAD: Dev formal verif tools for VLSI circuit & sys dsgn; dev & maintain CAD sys incl tech map for special cells & identify special constructs from HDL. PhD in EE, Comp Eng or Comp Sci reqd. $4833.83/mo. 40 hr/wk. Knlg of VLSI logic synth, formal verif, Binary Decision Diagrams, complrs, SIS (logic synth sys), Unix & C reqd. Job site/intrv: San Jose, CA. Send ad & resume to: IEEE Spectrum, Box 7-1, 345 East 47th St., New York, NY 10017.

Mfg's sales and svc office in Central OH seeking technical srv eng to install, troubleshoot and svc full line of fixed column and fixed bed precise computer numeric controlled machine equip; ensure proper on-site installa-

CLASSIFIED EMPLOYMENT OPPORTUNITIES

tion; train customer personnel (including other eng and tech support personnel); complete modifications to machinery, mechanics, electronics, and tooling to customer specs; supervise installation and svc of high precision milling, drilling and boring machinery; review and approve contracts with regard to design and construction safety specs; negotiate and coordinate client acceptance tests for precision fixed column and fixed bed machining centers; de-bug, repair and commission equipment; respond to technical inquiries from customers' engineering staff. Req Assoc Degree or two years of study in electrical or electronic engineering tech and 4 years of training, which must include instruction in all aspects of fixed column and fixed bed precise computer numeric controlled mach equip, or, in lieu of training, 5 years exp on fixed column and fixed bed precise computer numeric controlled machine equip and willing to undergo add'l training at employer's mfg facility in Eng for 3 months. Must be willing to travel 90% of the time throughout N Amer. No exp req 40 hrs/wk, 8:00-5:00, M-F, $44,100/yr. Must have proof of legal auth to work perm in U.S. Send resume in duplicate (no calls) to K. Shockey, Job# 00135, Ohio Bureau of Employment Services, P.O. Box 1618, Columbus, OH 43216.

Electrical engineer-design engineering department: Minimum masters degree in electrical engineering plus two years experience in similar position required. Duties include the design and development from concept to completion of hybrid ballasts and electromagnetic transformers for fluorescent and neon lighting applications utilizing a combination of magnetic and micro-processor based electronic circuit design; production engineering of the foregoing with regard to manufacturing, costs and customer acceptance; use of software applications to test and analyze circuits, conduct life and reliability tests under different environmental conditions; obtaining regulatory agency approval of ballasts and transformers; and recommendation of suggested projects and analysis of competitive products in the transformer field. Knowledge of and minimum two years of experience with SPICE, PCB, FORTRAN and computer aided test equipment including digital oscilloscopes, power analyzers, light chromatometers and spectrum analyzers essential. Excellent oral and written communications skill essential. Company is located in Mendenhall, Mississippi. U.S. citizenship or permanent residency required. Salary: $40,115 per year. Work week: Monday-Friday, 8:00 a.m. to 4:30 p.m.. Total work hours: 40 per week. Interested applicants should contact the Mississippi Employment Service, P.O. Box 511, 1016 Carroll Drive, Hazlehurst, MS 39083-0511. Job service #MS2684537.

Software Design Engineer: By August 1, 1994, please send resume to: Employment Security Department, E&T Division, Job # 430742-F, P.O. Box 9046, Olympia, WA 98507-9046. Job Order Number must be indicated on your response. Job Description: Designs, implements and tests software for micro computers following standard procedures. Designs and implements authoring tools, graphical user interface, and other modules for multimedia applications .and titles, utilizing "C" language and Windows operating system. Requirements: Bachelor's degree in Electrical Engineering, Computer Science, Mathematics or Physics; 6 months work or minimum of semester long or equivalent school thesis project experience in programming or computer software design utilizing "C" language to run on Microsoft Windows operating system; and design or implementation of hypertext or multimedia software applications to run on Microsoft windows operating system. Experience may be gained concurrently. Must have legal authority to work in the United States. Job Location: Seattle Area Employer. Salary: $37,500 - $46,500 per annum, depending on experience. Compensation package includes bonuses and stock options. 40 hours per week, flex time. EOE

Engineer, Process Development: Dev. 0.2 micron CMOS device & tech.; comp.-aided device charctrztn.; CAD simul. tool applic. PhD or foreign degree equiv. in EE, Comp. Eng. or Comp. Sci.; + 1 yr. exp. in job offrd. or in Research Eng. reqd. $5000/mo. 40 hr./wk. Exp. with CMOS device physic, charcterztn. & molding. (SOI, low temp. BSIM), and submicron CMOS device reliability. (oxide & hot carrier issue) reqd. Knlg. of VLSI tech., proc. & cirkit, and CAD tool (SUPREM, PISCES, SPICE, BERT) reqd. Job site/intrv.: San Jose, CA. Send ad & resume to IEEE Spectrum, Box 7-2, 345 East 47th St., New York, NY 10017. EOE.

Project Engineer: To audit and evaluate client manufacturing systems to determine degree of conformity with specific ISO requirements; to determine the effectiveness of the client's implemented quality control system in meeting specific ISO requirements. Extensive overnight travel required. In addition to five years' experience in engineering software quality assurance, applicants must have earned the Bachelor's degree in engineering, be a registered professional engineer, and achieved membership in a recognized professional quality assurance organization. 40 hours per week; $45,000 per year. Job Number NC 3033239, DOT code 019.167-014. Qualified applicants should send letters of application, resume with social security number, transcripts, copies of appropriate certificates, and the names of three persons who can attest to their professional ability to Job Service, 105 Briggs Avenue, Durham, North Carolina 27703 or nearest Job Service office.

Product Research and Development Engineer (Electrical), to perform industrial product research and development related to next generation induction motor drive control systems for automotive vehicle applications. Responsibilities include following in relation with said applications: High performance (robust and optimal) control algorithm design; Analysis, modeling and simulation; Development of electronic/computerized simulators, and controller development, integration, and testing. 40 hours per week; 8:00 am to 4:30 pm; $61,000 per annum. Job in Detroit, Michigan area. Require: PhD in Electrical Engineering and 2 years experience as Development Engineer or equivalent industrial experience. Ph.D. thesis in advanced control systems. The theoretical and practical competence must also be evidenced by several refereed publications in the areas of optimal/robust control theory, and its application (including physical implementation) to induction motor drive systems. The required experience must be in automotive industry and include: (1) analysis, simulation, operation, control algorithm development and testing of induction motor drive systems for automotive propulsion; (2) design and development of electronic circuits and systems; and (3) expertise in control design and simulation with "Matrix-X" software package. Send resume to 7310 Woodward Avenue, Room 415, Detroit, Michigan 48202. Reference No. 43794. Proof of legal right to permanently work in the U.S. will be required. Employer paid ad.

Independent Consulting Engineers: We are a privately-owned Marketing and Engineering Consulting Company seeking individuals worldwide with BS in Electrical Engineering or higher with ten years of industrial experience in the areas of power system analysis, design, EMS systems, and electrical machine design. Computer programming languages and excellent communication skills are a must. We have an extensive training program. Travel expenses, accommodation, and medical care will be provided to the overseas consultants on board for training by the company. If you meet above requirements, please forward your resume to: Dr. Ashok Agarwal, Managing Director, AGR Associates (Marketing/Travel/Engineering consultants), P.O. Box 1844, Upland, CA 91785, USA.

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Scanning
The Institute

Canada to link Sections

IEEE Canada has been awarded a C $85 000 grant to link all 23 of its Sections electronically. The goal of what is to be called IEEE Canada Electronic Services is to deliver those services quickly and uniformly throughout Region 7. Tasks include:
• Developing two-way e-mail/fax communications to distribute electronic newsletters and information to all members.
• Creating a database of members and company profiles that can be accessed by phone and connected to local computers.
• Developing a seamless connection to the main IEEE server and such other Internet services as Ask*IEEE and assorted databases and libraries.

The grant was awarded by the Canadian Network for the Advancement of Research, Industry, and Education. It will be used partly to buy a server and communications hardware and software and partly to pay three part-time computer specialists and train volunteers to work with them. The National Research Council and Bell-Northern Research in Ottawa will supply the volunteers.

The project is a joint development between IEEE Canada (Jacek Chrostowski is the Chapter/e-mail coordinator) and the Multimedia Communications Laboratory of the University of Ottawa, which is headed by dean of engineering Nicholas D. Georganas.

TInet issues first reports

The July issue of the IEEE newspaper, THE INSTITUTE, has published the first reports from TInet, the Institute network of correspondents around the world. These are IEEE members and THE INSTITUTE (and *IEEE Spectrum*) readers desirous of trying their hand at writing. About 30 answered the call earlier this year for people with a "nose for news" who would donate their time and knowledge to report on projects within their Regions.

TInet is growing and could use still more volunteers. If you'd like to write anything from one-paragraph-long "news notes" on up to long "think" pieces, contact Kenneth Moore, THE INSTITUTE'S editor in chief. He can be reached at:

THE INSTITUTE
IEEE Operations Center
445 Hoes Lane
Piscataway, NJ, USA 08855-1331
Fax: 908-562-1745
E-mail: institut@ieee.org

Traveling the information highway

The IEEE is anxious to help those of its members who are beginning to navigate the Internet, and who hope to gain access to the network's huge hoards of information, as well as communicate with other members.
• For a list of text files about the IEEE's information highway, send a message to info.email@ieee.org.
• For a text version of the Institute's eight-page e-mail guide, send a message to email.guide@ieee.org.

Coming
in Spectrum

RECYCLABLE DESIGN. The recycling movement is affecting electronics, starting right at the design stage and involving government, too. The first of two articles examines how three consumer products were transformed into components for resale and scrap for reprocessing. Designers will learn what they can do to make their products easier to recycle.

The other article considers the status worldwide of legislation requiring old equipment to be taken back by its makers. Here Germany's laws are perhaps the most advanced, the United States is lagging, and other countries have yet to deal with the matter.

SUBMERSIBLE VEHICLES. Autonomous underwater vehicles (AUVs) are on the verge of careers in marine sciences, the offshore oil industry, and the military. Swimming free and untethered, they could map the ocean bottom under the ice caps, inspect undersea structures, and recognize and help neutralize explosive sea mines. This staff-written report reviews the challenge of endowing the vehicles with useful intelligence, as well as the progress of several ambitious projects.

SURFACE-EMITTING LASER. By emitting light from its surface rather than its edge, a new type of laser chip heralds two-dimensional arrays of great power and density—and can be integrated with other optical elements. Engineering hurdles remain, but according to researchers at Sandia National Laboratory, applications might include optical-fiber communications, printing and scanning, and two-dimensional image recognition.

MECHATRONICS NOW. Scarcely more than a decade old, mechatronics—in which mechanical and electronic components are tightly coupled, at times on the same semiconductor substrate—is moving from aerospace technology into the mainstream of automotive engineering. It is even popping up in undergraduate curricula. Find out why this discipline, which had its origins in Japan, is now catching on in many parts of the world.

FIELD-PROGRAMMABLE GATE ARRAYS. Logic that efficiently aids microprocessors in manipulating and transporting data was once designed with application-specific ICs. Now it can be fabricated more easily with field-programmable gate arrays, if they have the right internal logic structures.

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